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HORIZONTAL ENGINE WITH PROELL VALVE GEAR.

AT the Glasgow Mining Exhibition, which took place last year, there was exhibited a horizontal engine with Proell valve gear, constructed by Messrs. T. McCulloch & Sons, of Kilmarnock, from the designs of the inventor. It is described by *Engineering* as follows: The piston is 12 in. in diameter, and has a stroke of 2 ft., making 220 strokes, or 110 revolutions, per minute. The main interest centers in the valve gear. Steam is admitted to each end of the cylinder by a separate valve (Fig. 2), and is exhausted by a slide valve worked by an eccentric in the usual way. From the same eccentric rod, motion is imparted to a bell-crank lever, which carries at each end a trip lever pivoted to it. Each trip lever is a bell-crank, the horizontal arm of which rests upon a stop or abutment, which rises and falls with the motion of the governor balls. The other arm is shod with steel, and as the main bell-crank vibrates, it comes in contact with a lever connected to the steam valve and opens the valve, raising it for a distance, and consequently for a part of the piston's stroke, dependent upon the height of the governor balls. At some portion of the travel, the bell-crank trip lever slips off the end of the valve lever, and the valve is immediately closed by the action of the spiral spring in the dash-pot above it. The whole of the mechanism is exceedingly simple and direct, and there are the fewest possible joints and points of wear between the governor and the valves. The steam passages are so short as to be scarcely worth consideration, and the diagrams obtained (Fig. 3) are exceedingly satisfactory.

The makers are so confident of the economy which results from the use of this gear, that they offer to sell the engines on the basis of a guarantee of coal consumption and regularity of speed, a method which ought to have commended itself to buyers long ago, but which is often put on one side by considerations of price; it being quite forgotten that the saving in first cost is often lost many times in the increased coal bill during every year the engine is at work.

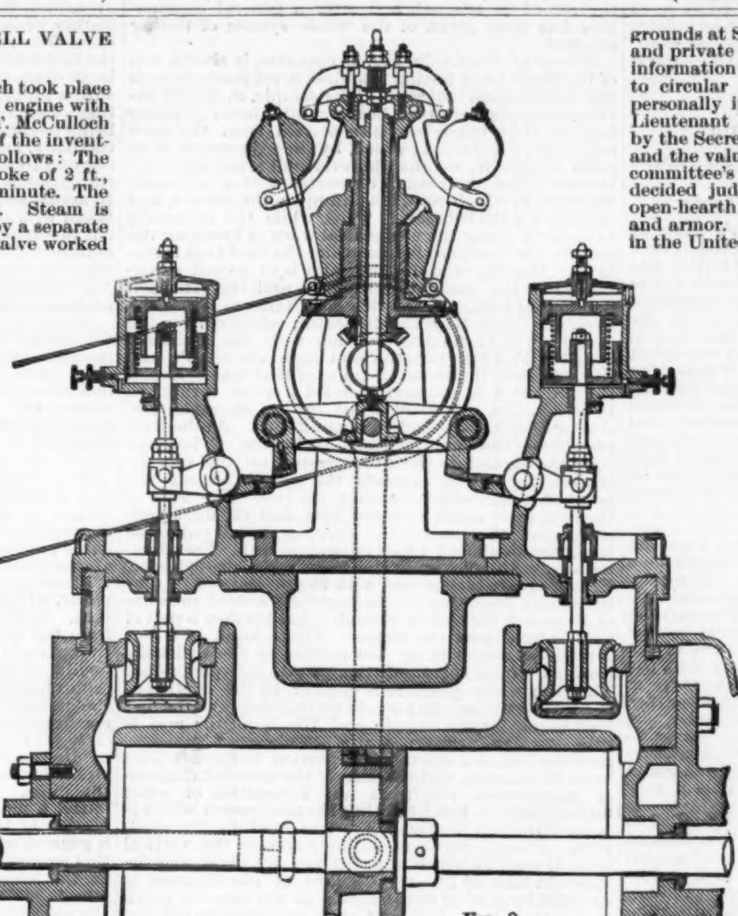


Fig. 2.

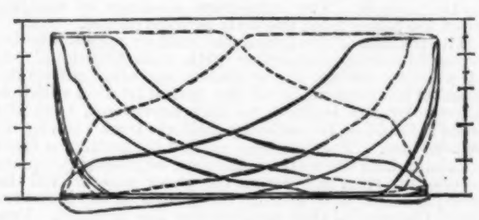


Fig. 3.

METALLIC DEFENSES OF THE STEEL WORKS OF THE UNITED STATES.

THE select committee of the United States Senate on steel-producing works in that country have presented their report. Members of the committee visited all the principal works and yards in the country, and two members who were in England during the past summer on private business took the opportunity to visit Woolwich Arsenal, Chatham Dockyard, the testing grounds at Shoeburyness, and other works of a public and private character in England. In addition to the information thus obtained, much was received in reply to circular letters from institutions which were not personally inspected by members of the committee. Lieutenant W. H. Jaques, of the navy, was detailed by the Secretary of the Navy to assist the committee, and the value of his services is acknowledged in the committee's report. The report says it is the final and decided judgment of the practical gunmakers that open-hearth steel is that best adapted for heavy guns and armor. The total production of open-hearth steel in the United States in 1883 was 133,689 short tons, but in 1882 there was made 160,542 tons, and the present estimated capacity is 550,000 net tons of ingots per annum. The committee summarizes its information relating to ores and steel manufacture as follows:

1. The United States is metallurgically independent for all purposes of warfare.

2. The manufacture of iron and steel for peaceful purposes has kept pace with the foremost science and skill of the world. For steel making the casting capacity is ample, but the heavy forging and finishing of guns and armor will require new and costly plants.

3. The machinery and machine tools of the navy yards are sufficient for the building of engines, but much of it is obsolete and no longer economical; the means of building iron or steel ships are lacking; one yard has a good plant of limited capacity for finishing steel guns, and has done some good work.

4. As a partial check upon private builders, and as a resource in case of necessity, some ships should be built in navy yards, the parts to be furnished by private foundries. Ships in general should be built by private contract, and private yards are capable of doing the work. The uncertain nature of repairs is such that some government yards should be kept ready to make them.

5. Armor plates and engines should be obtained wholly from private manufacturers.

6. The costly experiments of twenty-five years have reached a stage which justifies certain conclusions. Guns should be made of open-hearth steel, forged, breechloading, chambered, of calibers ranging from 5 to 16 inches, of lengths ranging from 30 to 35 calibers. Armor and projectiles should be made of forged steel. The hydraulic forging press produces better results than the steam hammer, costs much less, and should be used for government work. Ships should be constructed of steel, but certain minor classes may be composite, of steel and wood.

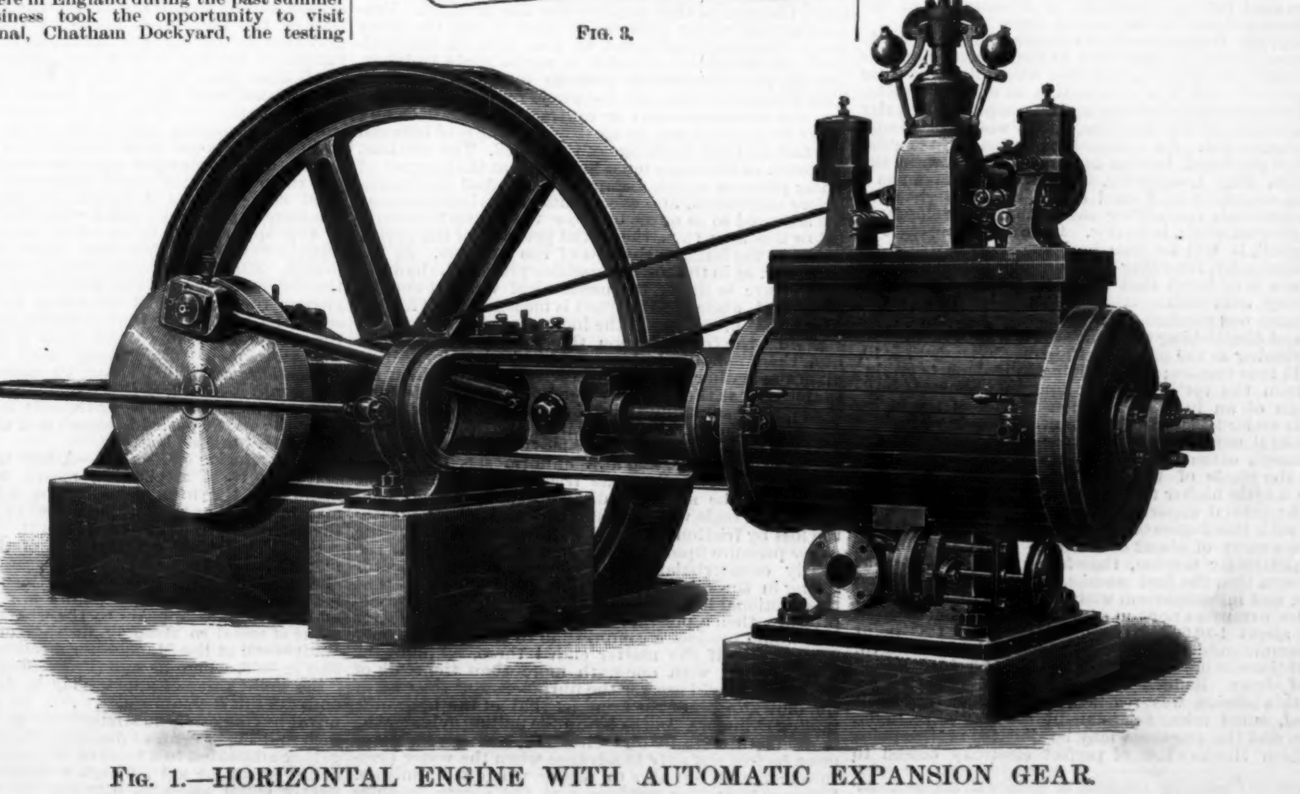


Fig. 1.—HORIZONTAL ENGINE WITH AUTOMATIC EXPANSION GEAR.

7. The manufacture of guns suitable for ships and coast defense should be divided between private foundries and government shops, the former providing the forged and tempered parts, and the latter finishing those parts and assembling them.

8. The government should establish the factories for machine finishing and assembling guns. The weight of opinion among army and navy experts and prominent manufacturers of heavy work in steel decidedly indicates the Washington Navy Yard and the Watervliet Arsenal as the best sites for such factories. When the determination to contract for heavy guns shall have been reached, the localities for finishing them can easily be determined.

9. All needed private capital is ready for cheerful co-operation with the government in whatever it may require.

10. Proposals for armor and guns should require such quantities and extend over such a series of years as to justify private persons in securing the best plant. Payments should be made only for completed work, and only the guaranteed bids of persons having capital and experience should be considered.

TEST RECORDING APPARATUS.

DESCRIPTION OF AN AUTOGRAPHIC TEST RECORDING APPARATUS.*

By Mr. J. Hartley Wicksteed, of Leeds.

In the discussion arising from the writer's paper at the summer meeting of this Institution at Leeds in 1882, on a "Single Lever Testing Machine," for testing the strength of iron and steel under statical loads, it was urged by Mr. Druitt Halpin that there was wanted a permanent record of all that was going on in the sample during the process of destruction. Referring to a machine he had seen, to which there was a diagram recording apparatus attached, he mentioned that "the sample was put in, and torn; and a complete diagram was obtained of the work done in getting the extension at every point, showing also the limit of elasticity, the breaking load, and the whole behavior of the sample right through the process." The writer replied that "with regard to the diagram recording apparatus, he hoped there would be an opportunity of hearing more about it. It was a thing that was much wanted, and he had no doubt it would be as applicable to one testing machine as to another. In the mean time the ordinary method of taking successive observations with dividers and calipers, and plotting the results upon a card, was extremely reliable, and could be carried out with microscopic accuracy." Through the courtesy of Mr. Halpin the writer subsequently became thoroughly acquainted with the arrangement of the machine alluded to; but he found not only that the apparatus was unsuited for use with any other type of machine than the one it was made for, but also that that type of machine was in his opinion a faulty one, both from the large angle through which its knife edges had to vibrate and also from the vertical motion imparted to its poise weight, which he considered would introduce unrecorded stresses on the sample of very considerable moment.

The attention of the writer had also been called to the subject of test diagrams by a paper, "On Certain Physical Tests and Properties of Mild Steel," contributed to the Iron and Steel Institute in May, 1882 (Journal, p. 11), by Mr. Edward Richards, of the Barrow Hematite Steel Works. In that paper the diagrammatic method was employed most effectively, but the diagrams had been plotted by hand, a most laborious process; in some instances the stress and extension were observed forty times during the progress of one test (page 13). It is clear that such observations require great skill and patience; but beyond the saving of time and labor there is also a further gain in obtaining the diagrams autographically, namely, that the progress of the test is continuous, without interruption from start to finish; and as time is a factor in the behavior of a test piece, it is important in making tests for comparison that there should be no irregularity in this factor. In the present paper the word "strain" will be used for the extension or deformation of the specimen, and not for the load or stress.

Autograph Diagram.—The autographic test recording apparatus to be described in the present paper is applicable to any testing machine where fluid pressure is employed; and it is so sensitive as even to register any stresses casually induced upon a sample by irregular manipulation of the machine, which would otherwise pass unrecorded. An enlarged copy of a self-recorded diagram produced by this apparatus is shown in the diagram, Fig. 1, opposite, which may be taken as a typical record for mild steel or for best wrought iron, these materials resembling each other very closely in their characteristic behavior. Following the trace of the pencil, it will be seen how the sample writes its autobiography, recording the tension put upon its fibers and how it endured that stress, first with unyielding elasticity, next with notable extension, till its climax of resistance was reached, and then with local deformation and diminishing resistance till it was broken.

Beginning at the point, A, the trace ascends to 5, 10, and 15 tons tension; and in doing so it departs gradually from the vertical datum line by about 1½ hundredths of an inch, or 1½ thousandths of the 10 in. length under tension; the amount of this departure or horizontal movement of the trace is the record of the specimen's extension, and it may be broadly stated that the whole of this gradual extension is elastic. With a little higher tension, at about 16¼ tons, a sudden horizontal departure takes place at B, showing that with this degree of tension the sample has yielded to the extent of about one-fiftieth of its length. At this particular tension, therefore, of 16¼ tons, it is at once seen that the first unmistakable strain has taken place, and in comparison with this at no previous load, for the extension per ton of load had previously been only about 1-10,000 of the length; but at this point the sample suddenly extended one-fiftieth of its length, or 200 times as much, within the range of a single added ton of stress. Refined experiments may show that before this tension was reached, and during the elastic period, some minute permanent set may have taken place, and the questions may be debated of the point at which Hooke's law of perfect elasticity ceased to operate, and why; but with this graphic record traced by the specimen itself there can be no question as to where it first yielded palpably and unmistakably to the tension, and suffered substantial deformation. For all structural purposes this may be considered the yielding point; and a reasonable factor of safety within this point is more to the purpose than an arbitrary factor within the point of maximum load, which climax of resistance by following the trace is found at C at 24 tons, after the piece has extended about 20 per cent. Following the trace yet further, a record is found of rapidly diminishing resistance on the part of the sample, together with further extension, until it finally snaps at F at 29 tons of load, having undergone a total extension of 25 per cent. of its length. This completes the self-recorded testimony of the sample. To the deductions that can be drawn from it, allusion will be made after the mechanism has been described by which the record is effected, and after a general explanation has been given of the whole system of testing adopted.

Record of Load.—In Fig. 2, opposite, is shown one of the single lever testing machines in conjunction with the autographic indicator. The sample, S, is held between an upper gripping box, A, and a lower gripping box, B. The upper box is suspended from the back center of a steelyard, L, which, by the adjustment of its poise weight, W, weighs whatever pull is put upon the sample. The lower box is connected with a hydraulic cylinder, F, which puts the pull upon the sample, and extends it until it breaks. Thus, while the hydraulic cylinder is doing the mechanical work of breaking the sample, the steelyard is measuring the load that it sustains. The object of the indicator is to record simultaneously the amount of the load and the extension due to that load. To get this simultaneous record the horizontal ram, R, of the indicator, which carries the pencil, P, is in fluid connection with the hydraulic cylinder, F, which puts the load upon the sample, and the indicator therefore partakes of that load. Round the outer end of the ram is coiled a spiral spring, C, 15 in. long, as shown in detail in Fig. 3, capable of closing 5 in. with a load of about 22 cwt. As the fluid pressure on the ram increases, the spring, C, becomes compressed, and as the fluid pressure on the ram decreases, the spring expands; the pencil records the point of equilibrium between the two. The area of the ram, R, is about 1 square inch, and the fluid pressure, when the machine is exerting its full pull of 50 tons, rises to about 1·1 tons per square inch. The effective area of the piston in the main hydraulic cylinder, F, is 50 square inches, and with the pressure of 1·1 tons per square inch there is consequently a total pressure of 55 tons on the piston, though it has to effect a pull of only 50 tons upon the sample. The margin of 5 tons is rendered necessary by the friction of the hydraulic leathers which surround the piston and piston-rod. Thus the water pressure is greater by the friction of the leathers than what would be due solely to the net load borne by the sample, and the indicator ram is subject to the gross pressure. This gross pressure, however, bears a constant proportion to the net load upon the sample, and the scale of the recorded diagram is constructed not from any calculation of areas under pressure, but by noting the net tension which is passed through the sample, as measured by the steelyard. The steelyard accordingly creates the vertical scale of load by which the diagram is valued, and the value in tons of the total height of the diagram is checked by poising the steelyard at the time the maximum strain is reached, and thus assigning to the diagram an indication of the veritable weight supported by the sample. The subsidiary readings of the diagram are taken from the scale so constructed.

The friction of the hydraulic leathers appears to increase in regular proportion with each additional ton of pressure within the cylinder; and after correct deduction has been made of the initial friction which is offered by the leathers to any movement, then the scale is found to be perfectly uniform from 1 ton up to 50 tons load This has been proved by putting a rigid specimen into the testing machine, adjusting the poise to one ton, then putting on the water pressure till the steelyard lifts, and letting the pencil of the indicator mark the card in that position for the first ton. Proceeding, the water pressure is slacked till the lever drops, the poise is adjusted to two tons on the steelyard, the hydraulic cylinder is again made to lift it, and the pencil records its position by a second mark. This is repeated through the whole range of the indicator, and no enlargement or contraction of scale or any other irregularity can be measured on the card between the first and last markings of the pencil. The zero line, however, of this scale must be made at that degree of water pressure which balances the initial resistances before mentioned, and check nuts on the indicator ram are adjusted so as never to allow the spring to press it below this line; thus the initial pressure of the spring balances the initial resistance of the leathers. In the indicator, as in the testing machine proper, the hydraulic pressure is doing the mechanical work of moving the pencil, while the steelyard is measuring the load of which that movement is the indication.

Besides the friction upon the leathers of the main ram, there remains to be considered also the friction upon the leather of the indicator ram itself, which for simplicity has thus far been omitted from consideration. Now, assuming that this friction is a steadily increasing quantity, as in the large ram, and assuming that the indicator were always moving in one direction, as the larger ram is, and at a uniform speed throughout the whole test, then the friction on the indicator ram might be similarly disregarded, by merely constructing a scale which should make allowance for it—the loss by friction being the difference between the water pressure upon the ram in one direction and the nearly counterbalancing pressure of the indicator spring in the other. Supposing, as is the case, that this frictional loss amounts to one-sixth of the whole pressure, then a pressure of 24 cwt. on the indicator ram would produce a compression in the spring of only 20 cwt.; and if the matter ended there, an indicator scale credited with one-sixth more than the scale of the spring would answer the purpose. But the case of the indicator is not the same as that of the hydraulic pulling cylinder. In the hydraulic pulling cylinder the motion is always in one direction; but the indicator must be free not only to advance when the water pressure increases, but also to recede when it diminishes. Between the water pressure and the spring pressure there must therefore be no difference caused by friction; for if there were, the water pressure might decline from 24 cwt. down to 20 cwt. before there was equilibrium of pressure in the water and in the spring; and it would have to decline further to about 16 cwt. before the excess of pressure in the spring would overcome the friction of the leather, and cause the pencil to travel back in response.

Freedom from Friction.—A means has accordingly been introduced into this indicator, by which the ram is set free from the impeding friction, and is thereby enabled to travel to and fro in response to the least possible difference of pressure between the water and the spring. This end is attained by the indicator ram being made to revolve by belt power and by gearing, Figs. 2 to 4. The driving power, being applied in a plane at right angles to the longitudinal travel of the ram, has no effect upon that travel; but it entirely overcomes the obstruction which the friction of the leather would otherwise offer to the free travel of the ram. The reality of the friction can be gathered from the fact that a belt is required 3 in. wide on pulleys 9 in. in diameter and making 120 revolutions per minute, with a purchase of two to one in the gearing transmitting about 1 horse-power, to overcome the friction; but being overcome circumferentially, it disappears longitudinally, and the ram becomes sensitive enough to respond to the very smallest want of balance between the opposite forces of the water pressure and the spring. In actual practice a diagram is one-fifth higher when taken with the ram revolving than when the ram is not revolving; and with the ram revolving, a record is obtained of any decrease in pressure, however slight, whereas a stationary ram needs a diminution amounting to nearly two-sixths of the whole load, or twice the friction of the leather, before the indicator records it.

Record of Extension.—For recording the extension of the sample simultaneously with the load upon it, the metallic paper on which the pencil travels is mounted on a brass barrel, D, like that of an ordinary steam indicator; and in accordance with the extension of the sample this barrel is made to revolve by means of the following arrangement: Two light clamps, J J, are attached to the sample on the datum lines between which the extension is to be measured. A fine wire with a weight at its end rests upon the lower clamp, and is thence led round a pulley on the upper clamp; thence it goes horizontally along a radius bar, G, through a slot in the upright casting of the testing machine proper; and passing round a second equal pulley at the joint of the horizontal and vertical radius bars, it descends to coil round the cylinder carrying the paper, which is counterweighted so as to keep the wire taut. If, however, it were allowed to descend direct from the second pulley to the barrel, it would happen that, should the sample sway to and fro or rise and fall bodily, so that the angle contained between the two radius bars themselves, or the angles contained between the radius bars and the vertical ends of the wire, became smaller or larger, the wire in passing round those changed angles would become shortened or lengthened by the amount of annular alteration measured on the circumference of the pulleys round which it passes at the joints. The wire would thus impart to the diagram barrel a movement which would not be due to any extension of the sample between the clips, but merely to a general movement of the whole bodily. To obviate this source of error, a third equal pulley is introduced at the lower joint of the vertical radius bar, and the wire is led over it to the barrel; and the variation in the arc which the wire covers on this third pulley compensates exactly for the variation in the arcs of the first and second pulleys through the change of angles made by the radius bars as the sample sways to and fro or moves bodily up and down. In other words, the wire begins with a plumb line ascending from where it rests upon the lower clamp up to the first pulley, and ends with a plumb line where it descends a few inches from the third pulley, at the foot of the vertical radius bar, down to the indicator barrel round which it coils; moreover, between these two plumb lines the three pulleys round which the wire passes are of equal diameter; hence the three arcs which the wire covers on their circumferences at any moment must together always add up to half the circumference of one of them, though the proportion borne by the several pulleys may vary as the angles of the radius bars change. The extent of this variation is quite immaterial, so long as it all takes place within the 180 deg. included between the upward and downward plumb lines of the wire. Hence, despite any general movement whatever of the sample, no rotation takes place of the indicator barrel except in response to an alteration in the distance between the clips clamped upon the sample.

A ruder apparatus would sufficiently well convey the total elongation of a sample, as required for general commercial purposes; but it requires all the refinement of this apparatus in order not to lose the record of the minute extensions that take place during the elastic period. Similarly, a water pressure indicator without the freedom from friction previously described might answer the purpose of recording, by an ascertained scale, the load at the time of first notable set, and also the maximum load carried; but it would not record the subsequent diminishing load during the local elongation, nor the load at the moment of fracture; nor would it record, as this indicator does, that curious phenomenon of fluctuating tenacity in the sample just after the elastic period is passed and when the first important set takes place.

Interpretation of Records.—A test sample being enabled by these mechanical means to record its own history in the form of a diagram, a few observations may be added as to the significance of that history and the inferences to be deduced from it.

First, by taking out the area of the diagram, the mechanical work expended throughout the stretching and breaking of the sample over the portion that lies between the two datum points is readily obtained; and this figure appears to the writer to embody that value of metal so strongly insisted on by Sir Joseph Whitworth at the Manchester meeting of this Institution in 1875, where he said (Proceedings, page 290) that "the great value of a metal lay in its tensile strength and ductility combined. . . . In the case of the metal having a tensile strength of 40 tons per square inch and 30 per cent. of ductility, these two figures together amounted to a total of 70; and it was a great achievement to get so high a total divided in such nearly equal amounts between the two qualities of

* Paper read before the Institution of Mechanical Engineers.—*Engineering.*

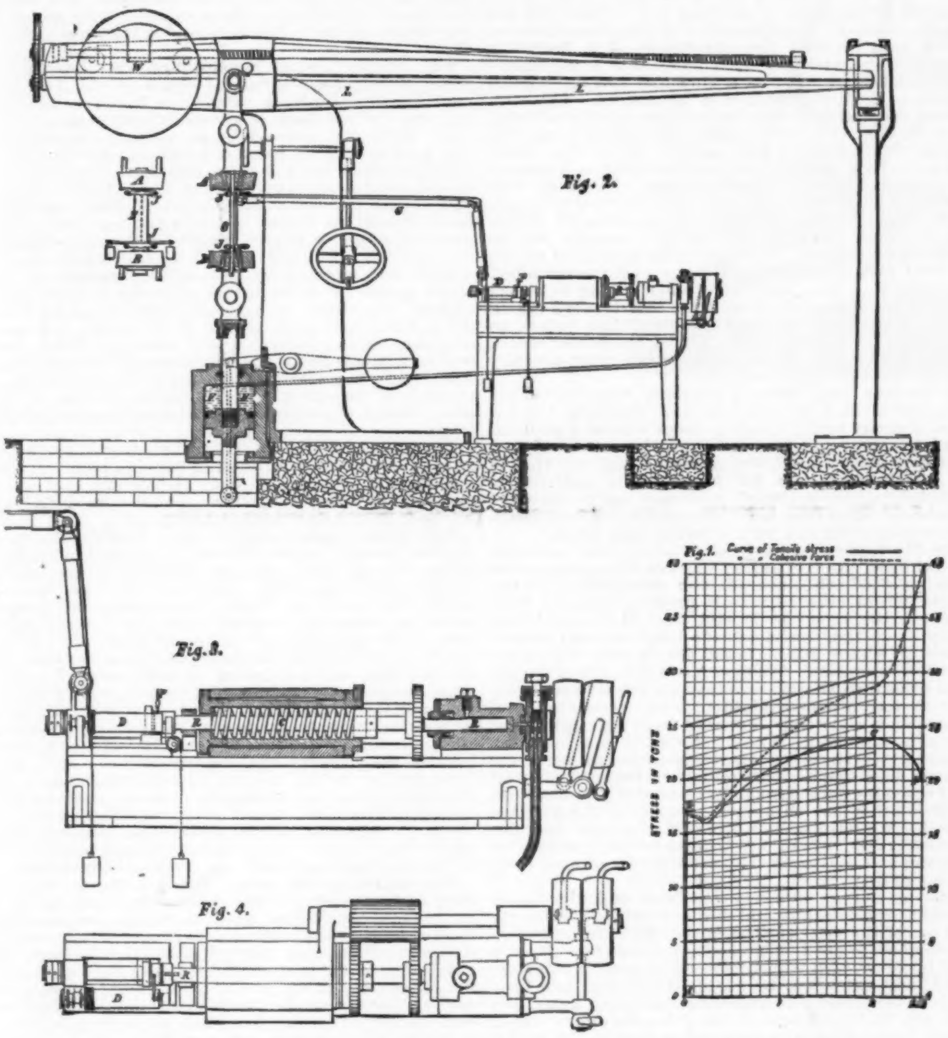
tensile strength and ductility." He proposed to add together the figures which represented the strength in tons per square inch and the ductility in percentage of extension, and to take the sum of these two as a basis for making a comparison between the gross mechanical values of two metals.

Pursuing this idea of taking into account both the ductility and the tensile resistance of a material, the value will be found to be best expressed by the mechanical work required to produce rupture. This is given by the area of the diagram, and may be conveniently expressed in inch tons, being the number of tons lifted 1 in. high which would represent the same work as has been expended in breaking the sample. Though this suggestion may be by no means a new one, yet with a diagram quickly and cheaply made it becomes more easy to carry out in practice, and is therefore worth fresh attention.

Second, after the point of first palpable yielding in the sample, the next most critical period is when its power to sustain the load begins to decline, which is shown by the descending line in the concluding portion of the diagram. After the climax of resistance has been reached, time alone would break the material without further increase of load; and as soon as the period of diminishing resistance has become established, it follows that the strains become localized till the sample is broken. The extension shown in the diagram (Fig. 1, below), from the climax at C to the point of fracture at F, took place within only a small portion of the length of the sample, near to the place of its fracture. In other words, up to the climax, C, the extension was general throughout the length of the sample; but beyond that point the general extension ceased, the sample determined where it was about to break, the flow of the material became localized, and the contraction of area became very rapid at that part. If the test is conducted at a speed just not fast enough to produce any sensible heating of the sample during its general extension, the writer has observed that a local heating may be detected just as soon as the resistance of the sample begins to diminish, and even before the local contraction is perceptible to the touch. The heating is an indication that the flow of material, which had previously been going on slowly over the whole length of the sample, has at this stage become more rapid over a short portion; and the further proof of this is the perceptible local contraction which very speedily follows.

The loss of power to sustain the maximum load, occurring as it does concurrently with the localization of the flow and with the local contraction of area, enables the point on the diagram to be marked at which local extension began. The importance of being able to mark this point is very great, because, whereas the general extension of the sample up to that point depends wholly on the quality of the material, the amount of the subsequent local extension up to fracture depends very largely upon the shape of the sample. It will therefore be seen that by cutting off this later portion of the diagram from the earlier, and giving the earlier or general extension in percentage of the length of the sample, a just comparison as to ductility of material may be made between experiments tried on samples that were not of identical shape or proportions. In illustration, suppose two samples be taken of the same material, each 10 in. long, one ½ in. in diameter and the other 1 in. in diameter, and both of them stretching 20 per cent. up to the climax, C; afterward the ½ in. sample during its local contraction of area will contribute say 2 per cent. more to the total extension, while the 1 in. sample will contribute about 5 per cent., raising the total extension to say 25 per cent., against the 22 per cent. total of the other sample. Thus the local extension, if included in the total, vitiates a comparison of the ductile qualities of the two samples. A stronger case is presented by a comparison between a long and a short specimen. Taking one sample 10 in. long and another of the same material 2 in. long, both of them giving 20 per cent. general extension up to the climax, C, they may both be assumed to give afterward ½ in. of further extension; in the 10 in. sample this addition contributes only 5 per cent. more to the total extension, but in the 2 in. sample it adds as much as 25 per cent., showing apparently for the 10 in. sample a total extension of only 25 per cent., but for the 2 in. sample a total of 45 per cent., although the material is absolutely identical in both. How much more then would the local extension vitiate a comparison between samples of not only unequal lengths but also unequal diameters; comparing, for instance, one sample 10 in. long and ½ in. in diameter with another 2 in. long and 1 in. in diameter, the local extension might here make the latter appear to possess more than twice as much ductility as the former, though in reality they are identical in quality, the material being the same.

It is quite impracticable to make all samples of uniform dimensions, for the simple reason that one sample may be from a thick plate or bar, another from a thin one; or a sample may be cut from a tire or a gun-coil or across an axle, where it is impossible to get more than a short length; moreover, in different countries where experiments are made, different measures are in use. But if the extension is given in percentage of the sample's own length, and if the portion which is due to local extension is kept out of the sum, then an expression is obtained which affords a fair comparison between any samples, no matter how they may differ in size, shape, proportion, or measurement. What has hitherto hindered the adoption of this solution for a difficulty long felt has, in the writer's view, been the difficulty and delay involved in stopping short during an experiment, in order to note the exact point at which the required extension should be recorded. With the autographic record, however, furnished by the indicator now described, there needs no stopping of the experiment, yet the different periods of extension can be readily separated by noting the altered character of the trace on the diagram. Further, by taking the area of the earlier part of the diagram, with the later portion cut off, the mechanical work done per cubic inch of the specimen can be ascertained apart from that portion which is influenced by the shape of the specimen—a mode of expression which would enable a single column of figures to give the essential comparison as to quality of material in all tests, however diverse. The plan of cutting off the later portion of the diagram has the further advantage that, in the event of a sample breaking outside the datum points marked upon it for measurement, it is not thereby precluded from a just comparison with other samples which have broken between the datum points.



TESTING MACHINE WITH AUTOGRAPHIC RECORDING APPARATUS.

In Fig. 1 the diagram shows a full line as traced by the pencil of the indicator, and a dotted line above it which has been plotted to show the cohesive force of the material. It will be observed that the dotted line rises to the very last, inasmuch as it is the result of reckoning the tons of load, not upon the original area of the sample, but upon the contracted area at each stage; thus at the moment of fracture, although the load had gone down to 20 tons, yet the area having contracted 50 per cent., it follows that the cohesive force per square inch had gone up to 40 tons. This explains to a great extent the enormous strength of cold drawn wire; for if a material with 50 per cent. ductility be drawn down into wire, although some of its ductility will thereby have been taken from it, yet on the other hand its elastic limit and the tensile strength which it had prior to this deformation will thereby have been raised enormously. The writer is indebted to Mr. Edward Richards' paper before mentioned (Journal of the Iron and Steel Institute, May, 1882, page 11) for the plotted line of cohesive force, or it may be called "intensity of stress." This line is easy to construct from the autograph diagram by means of only two calipered dimensions from the sample; and it can be done at leisure afterward, without having interrupted the progress of the test.

The plotted line of cohesive force has been made still easier to construct, so that only one calipering of the sample is needed, by the calculation of Professor Unwin recently given (*The Engineer*, May 29, 1885, page 419), in which he shows that, assuming the sample to be uniformly plastic throughout its length, as the writer takes it to be approximately up to this climax, then the percentage of contraction of area is equal to the percentage of elongation calculated on the stretched length of bar. It is equally true that the percentage of area lost, calculated on the remaining contracted area, is equal to the percentage of elongation calculated on the original length of bar. Having then in the typical diagram a bar that has stretched within its climax 20 per cent. of its original length with a load of 24 tons per square inch of original area, we find that this load is supported by an actual area of 0·833 square inch, the lost area being 0·167 square inch, which is 20 per cent. of that remaining; and the cohesive force or veritable stress is therefore 28·8 tons per square inch, or 20 per cent. greater than the nominal stress of 24 tons, the latter being the load shown by the steelyard as though supported by the full original area. The same relation between area and length holds good throughout the period of general extension. Hence, to plot a curve representing the intensity of stress, each ordinate to the curve of nominal stress, or of load shown by the steelyard, should be lengthened by a percentage equal to the ratio which its own abscissa bears to the original length of bar; and a convenient way of plotting this curve of veritable stress is the following: A scale is constructed for the climax which is 20 per cent. higher than the original scale; oblique lines are ruled across from this enlarged scale to the original one; and the curve is plotted by taking points where the load line intersects the horizontal lines of the original scale, and transferring these points vertically to the corresponding oblique lines which form the proportionally increasing scale. Each point of this plotted curve may then be taken as correct, supposing that the sample is uniformly plastic throughout the period of general extension; in so far as it may depart from being uniformly plastic, the curve as above plotted becomes only approximate and not minutely accurate.

At the place of fracture in the typical sample the reduction of area is found by calipering to be 50 per cent. of the original area; and as the sample breaks at 20 tons per square inch of the original area, the intensity of the stress is equal to 40 tons per square inch. The scale then to be constructed for this breaking point is twice the height of the original scale. The intermediate scale cannot, however, be obtained by the previous plan of ruling oblique lines, because during the local elongation the length subject to contraction of area is not constant, but becomes more and more restricted as the breaking point is approached. The concluding portion of the plotted curve, therefore, between the point corresponding with the climax of resistance and the point where the break occurs, is only hypothetical, as shown on the diagram.

The consideration of this increase in tenacity, taking place concurrently with a decreasing area, explains the invariable occurrence of localized extension ensuing immediately on diminishing gross resistance. For so long as the tenacity is increasing in a faster ratio than the area is diminishing, reduction of area serves only to produce increased resistance.* Under these conditions there is a strong stability of equilibrium as to the intensity of stress throughout the sample; and should any portion stretch locally, so as to contract its area and intensify its stress in advance of the other portions, it cannot long continue doing so, inasmuch as there ensues in that portion a resistance to further extension greater than in any other part of the sample; it will therefore refuse further extension till all the other parts have been equally extended and have set up an equal resistance. As soon, however, as the point is reached where the increase in tenacity goes on at no higher rate than the decrease in area, the stability of the equilibrium disappears; and if any portion of the sample contracts its area in the least degree more than the rest, it has no power of recovery, and becomes at once the weakest part, as the increase of its tenacity no longer keeps pace with the reduction of its area, nor raises its power of resistance above the other portions of the sample. The neighboring parts remain stronger to resist extension than itself, and thus the equilibrium of intensity can no longer be restored; it becomes more and more unstable, the intensity localizes itself more and more, till finally the material separates at a single plane of intensest stress. It is moreover impossible that the sample should continue stretching uniformly throughout its length after the condition of stable equilibrium is passed, for the reason that, if no accidental inequality should determine the place for local extension, then it will occur at the middle of the length of the sample, because this portion receives the

* See "Principles of estimating Safety and Danger in Structures," by Professor James Thomson, LL.D., Glasgow, 1874 (page 9).

least collateral support from the enlarged ends or from the friction of the gripping boxes.

Summary.—The autobiography written by every specimen of iron and steel that is strained to the breaking point in the testing machine may be epitomized as follows:

Supposing it to enter the machine in a state of ease, having no unequal stresses among its particles, its first stage is one of what has been called in this paper unyielding elasticity; it extends about $\frac{1}{1000}$ of its length per ton of load, but on the removal of the load it shows itself unstrained, recovering its former dimensions. During this period the equilibrium of stress is stable, and uniform throughout the sample.

Its second stage is a state of fluctuating strains and stresses. The bar yields about 2 per cent. of its length; and this strain is beyond recovery. The pencil of the indicator hesitates and almost trembles. There would seem to be a succession of local extensions in the bar, as was lately pointed out by Professor Kennedy (*Nature*, April 2, 1885). These local extensions evidently reduce the area locally in a higher ratio than the cohesive force increases; hence a condition of unstable equilibrium, which would lead at once to fracture, were it not that after a short critical interval the bar sets up increased resistance, and thus enters its third stage. Here stable equilibrium is restored; but the permanent strain increases in its ratio with every added ton, so that in the latter part of this stage the bar suffers as much extension from one ton as it does in the earlier part from 5 tons. During this stage the bar may stretch about 20 per cent. of its length.

The fourth stage is the last. The instability of the equilibrium recurs, but is not critical or fluctuating, as in the first notable yielding of the bar. There is no indecision in the pencil, but it steadily records a rapidly decreasing resistance, accompanied by a local strain, which, over the part where it occurs, is very much greater than in any preceding stage; for although the local extension over this part may be only 5 per cent. of the total length of the bar, it would, if contributed in the same proportion over the bar generally, be found to amount to about 80 per cent. of the original length.

Conclusion.—Finally, the writer would observe that, while the autographic record gives many data for research, it appears to him to possess the following advantages of the utmost practical importance in everyday engineering:

1. It records definitely and beyond question the load at which the material gives out in its elasticity and yields irrevocably under the stress.

2. The area of the diagram gives the gross mechanical value of the material.

3. By enabling the local extension about the breaking point to be separated from the general, it affords a means of making just comparisons between samples of different shapes. Only their initial sectional area needs to be known, and the scale of the diagram drawn to suit it. By this simple plan, whatever the size of the specimen may have been, the diagram can be read off throughout its stages in loads per square inch.

Lastly, the apparatus that has been described is self-acting in the strictest sense of the word; that is to say, it makes its record quite independently of the manipulation of the poise upon the steelyard. The most skillful manipulation could not adjust back that poise to keep pace with the rapidly decreasing resistance of the sample just before fracture, nor with its fluctuating resistance at the first notable yielding point; but whatever position the poise may occupy upon the steelyard, whether more or less than balancing the load upon the sample, the indicator makes its own independent record, free from any errors due to imperfect manipulation. It is therefore a record of such a character that, if attached to the sample by which it is made, it would form an indisputable mechanical voucher for the accuracy of the human rendering of results.

SOLID EMERY WHEELS.

By T. DUNKIN PARET.

THE manufacture of solid emery wheels may be considered a new industry, for the use of these goods was but small twenty years ago, and it is during this period that the demand has grown—the range of application increased and the need become more vital. Three things have contributed to the rise of this industry: The increased safety of use; the general introduction of machines designed to apply grinding wheels; and the extended use of steel, chilled iron, phosphor bronze, and malleable iron. It may appear singular that we omit what is usually the prime factor in an increased demand for new wares, namely, decreased prices. The fact is that, where solid emery wheels were the right things to use, their use secured so undoubted and large a profit that the highest price ever asked was only reasonable and moderate. During the last twenty years the price has fallen fifty per cent. or more, but such fall has been unreasonable and improper, for during that period the average quality of the goods has been greatly raised and their cost but slightly decreased. A reckless, cut-throat competition has well nigh demoralized the trade.

That solid emery wheels are much safer than formerly is mainly due to the general introduction of machinery specially designed for the application of such wheels, and to the fact that the larger part of this machinery is built by the manufacturers of the wheels. A fruitful cause of accident in old times was the imperfect mounting of an emery wheel when the user furnished his own machinery. In such cases the most radical mechanical errors were often made. Flanges were improperly turned; mandrels fitted so tightly that their expansion by heat cracked the wheels; and wheels were fastened to iron centers and flanges by bolts which went through holes bored in the wheels. Besides this, pulleys and counters were got up by guesswork, and the proper speed often greatly exceeded. Now, the counters are usually supplied with and adapted to the machine, the flanges carefully turned, and the holes in wheels made large enough to allow for expansion of the mandrels.

The increased safety is also partly due to the improved average quality of emery wheels and to the greater familiarity with their use. Undoubtedly all the manufacturers have surrounded their business with greater safeguards, and all makes are safer than formerly, though radical differences must exist to the last.

It is evident that all makes of emery wheels which depend upon vitrifaction must be brittle; that those which depend upon a chemical interchange slowly taking place through the body of the wheel must be always of uncertain quality; and that those which are baked, dried in ovens or otherwise (though not vitrified), and in which the change of quality progresses from the outside to the center, must be subject to unknown, variable, and unequal tension. The safety or danger of wheels which are a union of emery and some substance simply cohesive can be more readily calculated than that of any of the above. Wheels which consist of emery cemented by gum arabic, shellac, glue, bitumen, etc., are comparatively simple compounds, whose strength and other qualities may be reasonably calculated upon. Others have been made of more complex compounds, such as oxidized oil or mixtures of various cohesive substances.

Among the earlier makes was one composed of emery and melted brimstone. The manufacture of these ceased entirely long ago, and their use was accompanied with frequent accidents and many disagreeables. Another early make was based on the use of the soluble silicates—a use less understood then than now—and this make proved a failure also. A whole series of makes was founded, and many are still in use, based on the inventions of Sorel and of Ransome. In these cases exist the chemical interchanges of the oxides and chlorides of magnesium, and also of zinc, and as many modifications as are comprised in the almost countless patents for artificial stone. As has been already shown, all of these were liable to the defects due to the uncertainty of the chemical action inside of the mass and to unknown and unequal tension. As illustrative of uncertain chemical action may be cited the experience of a fledgeling manufacturer who had been hatched in a salesman's nest, and flew at once, as a chemical and mechanical expert, to the high perch of a laboratory. This scrupulous scientist at once introduced an amount of detail into his laboratory which was intended to secure the maximum of certainty and safety. With him there was to be no trusting to so loose a thing as a general standard and broad general average. From the very substance of every wheel made he moulded a sample stick, which, labeled in duplicate, was filed for future examination. Luckily for him, his business was in that state when the shipments were mainly of wheels *on trial*, most of which—still more luckily—remained untried. For, at a later stage, when, owing to severe commercial depression, even *trial wheels* were not in demand, and time was more plentiful than orders, an examination disclosed the fact to the horror struck expert that most of his sample sticks were actually falling to pieces on the shelves.

In another case, where a company was started by some uneducated laborers, who were struck by the low price of emery and the high price of wheels, a material was introduced in large quantity whose only object, as their patent stated, was a mechanical one, that is to say, it was used for its friability only. Unfortunately, the material possessed active chemical properties which they knew nothing about, and manifested its activity in a most disorganizing manner.

As illustrative of unequal tension may be cited several facts. In the earlier years of this industry the warping of wheels was a common occurrence, and the proportion of cracked wheels greatly exceeded that which exists now. It is said that in one instance, many years ago, the buyers of a large stock of wheels, nearly all singly boxed, found that a majority of the wheels were cracked. We have seen a thin wheel warped so as to be dish shaped—concave on one side and convex on the other—straightened by having a bevel turned on it and being converted from a straight faced into a saw-gumming wheel. We have seen very thin wheels which showed a great disposition to warp and become dish shaped. Examination disclosed the fact that the sides were turned first and the face last. On reversing this, and turning the face first, the warpage ceased. We have seen wheels, lathe turned and mechanically true, which, being heated while free from all pressure and constraint, twisted and turned so as to be all out of line.

The maximum of safety has been undoubtedly attained in the vulcanite and tanite wheels. The former was one of the very earliest in the field, and probably the earliest to meet with a genuine success. It is a fact, however, that while the range of uses for vulcanite has widely extended, no material advance has been made in the quality of vulcanite for many years, and this same fact holds true of the vulcanite emery wheel, which probably was as safe and as good in the earlier years of its manufacture as it is now.

The latter—the tanite wheel—was the result of an avowed attempt to introduce, for a wide range of uses, an entirely new material which should equal or surpass vulcanite. The adaptation of tanite for use with emery was one of its latest applications, and was not made by the actual inventor of tanite.* Before a single tanite emery wheel had been made, years of experiment had been spent on tanite pure and simple, with the view of securing for it the qualities which made vulcanite so unique an invention. Jewelry, buttons, chains, checkers, dominos, chessmen and chess boards, casters, billiard balls, daguerreotype cases, etc., etc., were all made of tanite, whose luster, blackness, and polish rivaled the Whitby jet. The blackness was unchangeable, tanite not becoming dull or brownish yellow, as the vulcanite often did, from the efflorescence of the sulphur; neither did it tarnish silver; nor did it attract dust, as vulcanite sometimes did, owing to its electrical qualities. Tanite was worked with equal ease in the turning lathe, like ivory, and in the hot press, where it took the finest and most elaborate designs. In these years of experiment the most delicate questions were worked out as to its plasticity, its homogeneousness, its elasticity, its cohesiveness, and its powers of conduction. As the result of these efforts tanite became a new material—in no sense a compound—and an invention as unique as that of vulcanite. One of the highest chemical authorities in Great Britain—Prof. Penney, of Glasgow, the only chemist who was ever admitted to any knowledge of the process—declared that the invention was absolutely novel and the methods employed unknown to chemists.

Among the various makes of emery wheels, vulcanite and tanite stand alone as being the only ones whose qualities depend upon the combination of emery with a distinct compound matrix or base.

It is the manifest duty of users of emery wheels to employ all reasonable methods to insure the safety of their wheels; but we lay it down as a cardinal principle that no wheel should be used which is not safe without special mechanical aids or re-enforcements. One exception only we note, and that is in the case of very thin wheels. Wheels of ¼ inch and less in thickness, which are perfectly adapted to stand the regular speed without bursting, are yet liable to be broken by side pressure. It is perfectly proper, therefore, when ⅛ or ¼ inch wheels are used, to employ flanges of metal or wood, or of both, wide enough to cover the greater part of the diameter of the wheel. But such use should not lead to any mistake as to the proper function of a flange or to an unreasonable reliance upon it. In the case indicated above, the object of the flanges, which cover nearly the whole sides of the wheel, is not to hold the wheel in and keep it from flying from its center, but to keep it from getting broken by side pressure. It is advisable to discountenance the use of wide flanges on all but very thin wheels, as the use of wide flanges leads to a confidence which is utterly unwarranted. In the earlier years of this industry, the belief was a prevalent one (and still exists to some extent) that flanges were a great safeguard, because they would hold the pieces of a wheel in if it should burst. How untrustworthy such a reliance would be can easily be understood by a mechanic who takes the trouble to actually figure the force involved in the explosion of a wheel running at the rate of a mile a minute, or by any ordinary workman who has seen such explosions or their effects.

The Tanite Co., of Stroudsburg, Pa., has for its wheel testing room a regular bomb proof. This is a semi detached building with walls from four to three and one-half feet thick, of unusually large stone. Upon these walls, and covered by an ordinary shingle roof, lies a false roof of huge oak logs laid side by side as closely as the space will allow, and these logs are covered and weighted down by a mass of huge boulder stones hauled from the surrounding fields. Within this bomb proof stands the testing machine, run by a belt which passes through a narrow fissure in the rear wall to a countershaft protected behind it, and which can be started and stopped by one entirely outside of the bomb proof. The fragments of bursting wheels have broken the stones as masons' hammers might have done—have cut great gashes in the tough oak logs, and sometimes penetrated and stuck in them. One who sees in this havoc the mightiness of the spent force will realize how little the pressure of an iron flange on the side of an emery wheel would accomplish if that wheel lacked the cohesion to withstand the centrifugal force.

The proper function of flanges is to so grip the wheel as to prevent it from turning or running loose upon its spindle, and to so fasten it to the spindle that wheel and spindle revolve together. The flanges should not be relied on as an element of safety.

This same consideration renders inadvisable, *as a general thing*, the use of hoods, cowls, and safety coverings, though there are some cases where these might be used with advantage. As a matter of fact, the majority of wheels are needed for so many uses, and require the work to be applied to them in so many ways, that it is not practicable to inclose them. But where they can be inclosed, the doubt at once arises whether the so-called safety covering is really safe. To withstand the tremendous blow of a bursting emery wheel, the safety covering must be of wonderful strength. Supposing it to be made of metal sufficiently strong, the probabilities are that it would be fastened to some part of the grinding machine (cast iron as a rule) or to floor, roof, or walls. Under these circumstances some breakage would be extremely probable, and our conviction is that the use of such coverings would be likely to engender a false confidence. If used, they ought to be of some tough metal—wrought iron or soft steel—and they ought to be secured with great care.

The writer of this article directed the course of a long and expensive series of experiments on this subject. Cast cowls were tried of various metals other than cast iron, and supposed to be much tougher and stronger. Breakages proved that the temper and toughness of each cowl differed, and that they were not absolutely safe. Cowls made of soft sheet steel, arched, banded, and ribbed in complicated fashion, were found to be proof against all blows; but these were weighty, costly, and unsightly. The ultimate conclusion was that they could not often be used, and that their introduction would arouse among the workmen a dread of wheels which would cause them to demand safety coverings, while the expense of absolutely safe ones would be so great as to practically encourage the manufacture of low priced and unreliable ones.

The reasons which negative the use of flanges and cowls as means of safety, negative also the use of wire webbed wheels and of all makes which are advertised to do full work at half speed.

The results attained by emery wheels have never been observed with enough of scientific method to determine positively the best working speed. All of the first-class makers unite in advising a speed of about a mile a minute—5,000 to 6,000 feet—for a point on the face of wheel. We have every reason to believe that many wheels intended to be run at the above speed are run at an actual speed almost double. Whether the doubled speed gives proportionate increase of results has not been demonstrated; but it may be said beyond all question that a wheel will not do as much work at 2,500 feet as at 5,000, and the claim of full work at low speed is intended to secure the introduction of wheels which would not be safe at 5,000.

We have said that one cause of the increased safety of emery wheels was the greater familiarity with their use. One who considers carefully the ordinary conditions of use will appreciate the necessity of only using such wheels as offer the maximum of safety. Every wheel without exception is a thing which may explode with terrific force if too high speed causes a breaking strain. In model factories, with superb engines, heavy fly wheels, perfect steam governors, scientific superintendents, and first-class belting, known and uniform speeds may be depended upon; but in thousands of places where emery wheels are run the conditions are those of uncertainty and variability. To begin with, many men—even foremen in large shops—do not know

* The first combination of tanite with emery was made by an American, Mr. Abijah Wallace, formerly superintendent of the Scottish Vulcanite Co. of Edinburgh.

how to calculate the speed of countershafts when they have as factors the speed of engine, water wheel, or main shaft and the diameter of pulleys. Therefore many grinding machines are mounted by guesswork, and the grossest errors made.

The surest safeguard against over-speeding is the testing of the very spindle which carries the emery wheel with a speed indicator. These can be bought for a few dollars, and are sure, reliable, simple, and easy of application. But errors may occur even then. The spindle may be timed when the average amount of machinery is attached to water wheel or engine, and in this case the *average* speed might be shown. But governors do not always respond quickly—especially those of water wheels—and the quick throwing out of gear of heavy machinery and slow action of governor may result in a very sudden increase of speed in the emery wheel to a point far beyond the maximum.

We once saw an emery wheel burst—harmlessly—when being exhibited to a party of visitors by the superintendent of a factory. The machine on which the wheel was run had a cone pulley, and the belt was arranged to give the proper speed of wheel at the ordinary speed of main shaft. Owing to starting of heavy machinery and slow action of governor, the speed of wheel was so much reduced that the comet-like stream of sparks shortened and failed of its usual brilliancy. The disappointed exhibitor threw the belt on to different pulleys, and almost at the same instant the heavy machinery was thrown out of gear, and the speed, multiplied by various pulleys and countershafts, was increased so enormously that the wheel burst into fragments.

Again, an often unsuspected cause of error is in the slip of belts. A wheel might be timed at mounting when one or more belts on main or intermediate shafts were slack. The tightening of these might lead to an immensely increased speed.

A most extraordinary cause of accident was once discovered in the faulty construction of a turbine wheel. The testing machine of an emery wheel factory was most carefully planned, so that each of its many pulleys should give a definite speed, the maximum speed of testing machine spindle being based on speed of main shaft when the turbine wheel was running at full gate. For a long while all went satisfactorily; but at last more and more of the wheels began to burst at the high test speeds. The workmen suggested that the test speed should be lowered; but the proprietor said, "No! If the wheels were going to burst, they must do so in his factory, not in some one else's; before they were sold, not after." And so the wheels went on bursting, and the factory was turned upside down in the endeavor to find out who was responsible for the making of so many damaged goods. Chemicals were examined, processes investigated, and consternation reigned at the fact that the art of wheel making had been lost. A workman finally suggested that the testing machine ran at a much higher speed than usual; but this suggestion was ridiculed on the ground that the machine couldn't beat its own highest speed, and that the speed tests were based on the maximum speed of the main shaft. "Yes!" said the workman, "but now the water wheel was running only part gate, and ran faster." This statement seemed more unreasonable still, but investigation demonstrated the fact that with part gate the turbine wheel actually did run much faster than at full gate; and this increased speed of water wheel was so multiplied by the time it reached the emery wheel as to make thousands of revolutions in excess of the highest speed calculated upon.

Again, we would say that the best policy is to buy only such wheels as are made by manufacturers of long established reputation, and which such makers direct to be used at high speeds, neither urging extra large flanges, nor safety guards, nor strengthening webs, nor claiming full work at half speed.

We know of one instance where a large manufacturing firm which bought in this way had a fatal accident. A suit was instituted by the administrator of the man killed, claiming heavy damages on the ground of culpable negligence, inasmuch as the wheels were run at a higher speed than that advised by the maker. The manufacturer visited the emery wheel factory, tested speeds of water wheel, intermediate shafting, and testing machine, and a diagram and statement were sworn to whose object was to prove that the wheels were perfectly safe even if run at speeds greatly in excess of those advised by the maker. The manufacturer in question stated that the general feeling in his factory as to the safety of emery wheels was such that in case of an accident like the slipping off of the governor belt, and consequent running away of the engine, which necessitated the sudden stopping of machinery, the men hurried from room to room to shut off machines, but that the emery wheels were the last things thought of.

We have known accidents to occur from the most reckless carelessness in the use of wheels, and we have known inventions whose object was greater safety and whose result was greater danger. As an illustration of the first, we may mention the case of a man who bought at a village hardware store a thin saw-gumming wheel of a make which was known to be affected by moisture. The man had a long way to go, and it was raining torrents, so he was advised to leave the wheel; but, wrapping it up in a newspaper, he threw it in his wagon and started off. On reaching home, the soft and pulpy surfaced wheel was put in the oven of the kitchen stove and baked dry. The next day it was mounted and killed its buyer.

As illustration of the second, we may mention the case of an emery wheel salesman who satisfied himself that the first break in a wheel always occurred at the mandrel hole. He reasoned that if the wheel could be kept from breaking at the mandrel hole, it could not break at all. Accordingly, he had some wheels made in which a steel wire wound in a coil was moulded into the substance of the wheel around the mandrel hole. The result was that at a speed much lower than the usual test speed the wheels burst—all outside of the coil flying off.

The safety of emery wheel use would be increased if dealers applied a simple test to each wheel when they sold it, that is, the tap of the hammer.

This hammer-tap test should be applied as often and as carefully to emery wheels as to car wheels. The salesman and the user would soon become accustomed to the sound of perfect wheels, of any make they handled; and the clear ring which distinguished the good wheel would soon be recognized, while the dull, dead sound would suggest some unseen crack or structural change. Emery wheels in use should have regular inspections, for use is often accompanied by abuse, and wheels of perfect make so greatly and suddenly heated by excessive pressure that expansion and contraction of irresistible force open fissures which are finally destructive.

The cause which tends most to put dangerous goods on the market is the demoralizing craze for low priced wares which has for years past affected the market. During the last few years numerous new concerns have started, whose low prices have procured a wide sale, though neither maker nor user had any experience of the make. This tendency to buy low priced goods has always acted injuriously upon the manufacture of *grinding machinery* in the United States.

We are accustomed to laugh at the heavy, cumbersome machinery built by the British, and to point at the Englishman's body, and horse, and furniture, and machinery, is here the right thing in the right place. "Metal, metal, more metal"—this ought to be the cry of all American makers and users of grinding machinery. The typical grinding machine should be as wide based and solid as a pyramid.

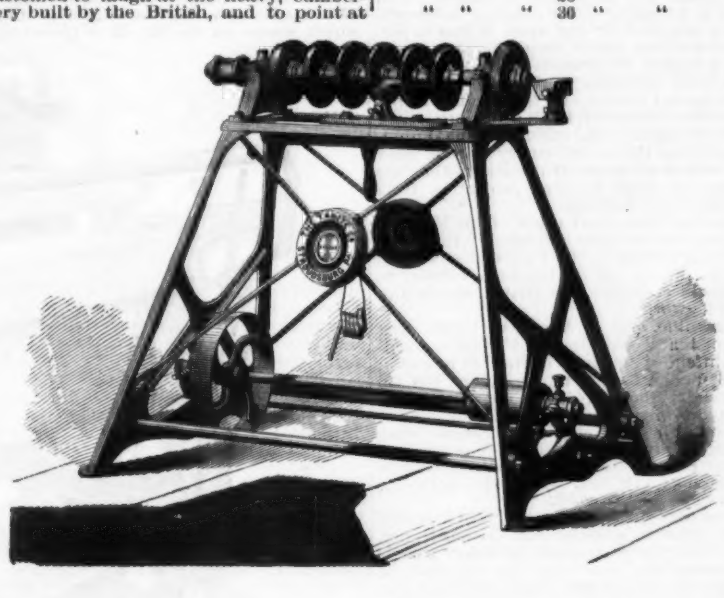
How unfavorably the American grinding machines compare with the foreign may be readily seen by the comparison of a few:

BRITISH MACHINES.

To carry	wheels	12	inch	diameter,	weight	577	lb.
"	"	"	14	"	"	"	620	"
"	"	"	20	"	"	"	864	"
"	"	"	36	"	"	"	2,320	"

AMERICAN MACHINES.

To carry	wheels	12	inch	diameter,	weight	156	lb.
"	"	"	14	"	"	"	275	"
"	"	"	20	"	"	"	503	"
"	"	"	36	"	"	"	2,519	"



the misplaced metal and the strength where none is called for. We have seen the hinge of an English stove which was heavy enough to hang a barn door. In many cases our laughing criticism is just, and American designs have admirably combined strength with lightness. But when it comes to grinding machinery, the British and some, if not most, of the Continental nations are as manifestly in the right as we are in the wrong. It is not enough that a grinding machine shall be heavy enough to hold up the weight of the emery wheels, or strong enough, if bolted to the floor, to remain in its place. These machines are to carry wheels of varying weights at high velocities, and in very few cases will these wheels be perfectly balanced. The vibration which can be set up by an unbalanced emery wheel revolving at the rate of a mile a minute is scarcely imagined by ordinary workmen. If the educated foreman will carefully study Mr. Chas. T. Porter's recent lectures, as published in the SCIENTIFIC AMERICAN SUPPLEMENT,* and apply his facts to the use of emery wheels, he can readily get at approximately accurate data in any case. Suffice it here to say that an unbalanced emery wheel on a light weight machine will jump—as the workmen say—will shake the whole machine, communicate its vibrations to the floor, and finally to the whole building. Such jumping is a source of danger, a waste of power, a general annoyance, and, in time, a general injury. The mere stiffness of a grinding machine, though a good thing, is not enough; and the element of weight, which is typical of

The above figures are not claimed to give the average difference, but are taken from one catalogue of each country, and wide variations may be found in other catalogues. We take it, however, that the weights given above for American grinding machines are fully as high as the average, and we know that many are sold whose wheel-carrying capacities are represented to be as great as those given above, while their weights are much less. Now, our own most emphatic opinion is that all of the American machines given above are very much too light, though it will be noticed that the American machine for 36 inch wheels is heavier than the British.

That these machines are not heavier is the fault of the user or buyer, not of the maker; for the user and buyer complain that these machines are too high priced, and demand others for less money.

The newest list we have seen gives the following:

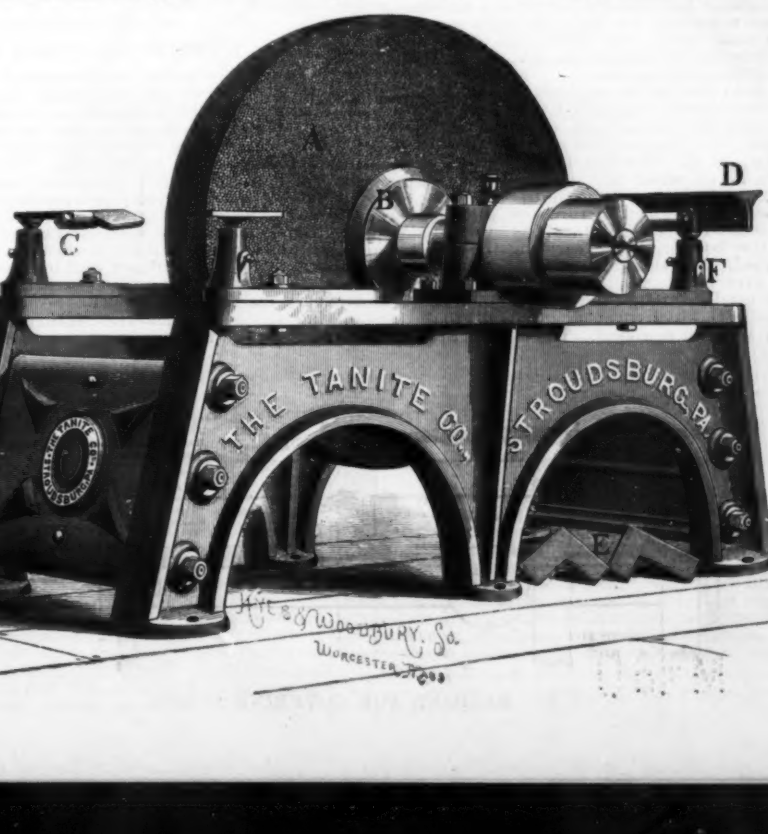
AMERICAN MACHINES.

To carry	6	in.	wheels,	weight,	9	lb.	price,	$5.00
"	"	10	"	"	25	"	"	10.00
"	"	12	"	"	40	"	"	15.00

Discount, 40 per cent.

Here we have a 40 lb. machine, at $9 net, competing with an American machine of 156 lb. and a British machine of 577 lb. The above comparisons are not exact, for the catalogues are not always clear as to overhead work, etc., being included or excluded; but allowing ample margin for such variations, the facts indicate clearly the superiority of British practice as regards the weight of grinding machines, and the ten-

* Sibley College Lectures, by the Cornell University Non-Resident Lecturers in Mechanical Engineering. Chas. T. Porter, SCIENTIFIC AMERICAN SUPPLEMENT, March 6 and March 13, 1886.



dency of a low priced competition to still further lower the American practice.

The vibration of over-light grinding machines is undoubtedly a danger, though possibly not a very great one, while the maximum of weight and solidity would tend to greater safety. We apprehend, however, that the most important effects of vibration are shown in the variation of results from the use of emery wheels, and that this factor is one whose importance scarcely any one has recognized. We have some remarkable facts bearing on this point, which must be reserved for another article.

The two illustrations which follow well explain the extremes of lightness and weight.

The machine first shown is intended to carry seven emery wheels, and yet weighs only 223 lb. This machine is in reality even more of a spider web than it appears to be on paper. The diagonal bracing rods are only ⅜ of an inch in diameter, and the cast iron frames are only about ⅜ of an inch in thickness. And yet this machine is deceptive in the extreme, inasmuch as it is far better adapted for the work it has to perform than many another which seems more massive. This machine is a typical illustration of that combination of strength with lightness to which we have alluded. The feet spread widely, and the machine slopes inward from the base to the top in all directions, while the rods and ribs strengthen and stiffen to a maximum. It must be noted that the seven emery wheels only reach the total weight of about 21 lb., and as they are 8 inches in diameter their extreme projection from center of machine is only 4 inches.

We well remember the actual anger of an Englishman on first seeing one of these machines. He asked in derision if we had no iron in the United States; and when requested to pull or lift the machine, refused to try. Nothing would convince him that it was in any way adapted for its work.

The second machine, also of American make, was originally designed and built for the French Government, and was intended to carry a wheel 36 inches in diameter and 8 inches face, weighing about 800 lb. The machine weighs about 2,400 lb., and is probably heaver than any ordinary grinding machine used in the United States. When one considers, however, that the machine weighs only about three times as much as the emery wheel it is to carry, the disproportion is evident; and, massive, low, and wide based as this is, it is even yet too light for the work.

The fact is that ever since the emery wheel industry began its rapid growth, popular opinion has leaned toward the view that the price asked for emery wheels was an extortionate one, and that the attempts of emery wheel makers to introduce their own makes of grinding machines were mere traps to make trade. The first of these ideas was tersely expressed in a letter which has just passed through our hands. The writer said that the idea of one emery wheel being better than another was all a notion of the maker, and that a $4 wheel was just as good as a $26 one. If men are willing to buy wheels only, they can buy at a low price; but if they expect to get wheel and experience at the same time, they must be prepared to pay for both.

The manufacture of grinding machines is not a very difficult thing. The manufacture and use of solid emery wheels is difficult, is susceptible of great progress, and has scarcely begun to be based on scientific principles. It is the aim of the best makers to have the emery wheel considered as a high class tool, to be well used by expert men, and makers and users should unite their efforts to remove this industry from the position of uncertainty and skeptical tolerance which seems to characterize it. The time will come when it will be as possible to state the results attainable in a given case by the use of emery wheels as it is now with lathe, engine, or boiler. Till then the experienced maker will be at the mercy of any discontented workman or jibing foreman who chooses to give the emery wheel dog a bad name; and low priced goods will be considered cheap without reference to average safety or to average results.

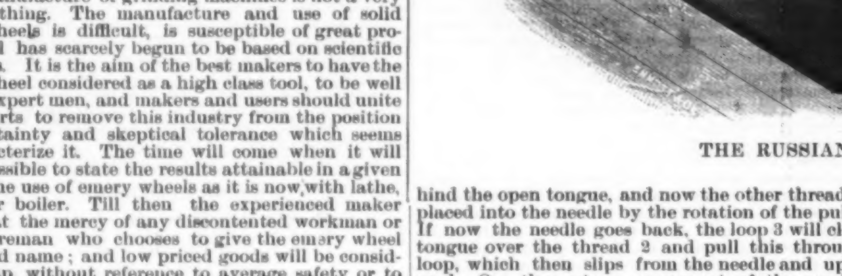
MACHINE FOR COVERING CORDS.

Plain hempen or cotton cords are often covered with a better material, such as worsted, silk, or both, to produce dress trimmings or to serve for other ornamental purposes. It is, therefore, in many cases, desirable to have this covering as ornamental as possible, and a Saxon manufacturer has therefore invented a machine which produces a pattern on the cord which can be diversified in many ways. Our illustration shows in Fig. 1 a vertical section of the machine, and in Fig. 2 the details of the action of the needle.

The main shaft of the machine is at A, and drives by means of the bevel wheels, B, B¹, the sideshaft, C, while it also gives revolution to the executer, H, keyed on it. The shaft, C, in its turn drives, by means of the pinion, D, the wheel, E. This wheel, E, is covered in front by a plate, E¹, on which the spindles for the bobbins are bolted, which carry the yarn to be used for covering the cord. The wheel, E, turns on a hollow bush, T, while behind this the pulley, X, is situated, which holds the bobbin, W, for carrying the cord or core to be covered. The spring, Y, presses against the bobbin, W, to give to the cord, L, the required tension. This cord is carried through the bush, T, then passes under the needle, O, which covers it, and finally to the bobbin, W¹, on which it is wound. The threads to be used for covering the cord are carried through the guides, G, to the needle; in the present case, two threads are shown, and are marked 2 and 3.

The action of the machine is as follows: While the pulley, E, revolves, the needle, O, makes as many movements forward and backward as there are bobbins with the yarn for covering; in the present case thus only two passages. This reciprocating motion of the needle is produced by the executer, H, the lever, I, and the rod, K, the latter being surrounded by a spiral spring, L, which presses the lever against the executer, and thus constantly pushes the needle forward, while the executer brings it back. The tongued needle, O, is attached to the rod, K, by means of the holder, N. Closely under the needle the bar, M, is situated, which is attached to the seating of the rod, K. When the two threads 2 and 3 have been attached to the cord, the open needle receives, on the pulley, E, turning, the thread 3; if now the needle advances, this thread will slip over the tongue and on the shank of the needle. The needle now recedes so much that the thread 3, which abuts on the bar, M, is placed immediately behind the open tongue, and now the other thread—2—is placed into the needle by the rotation of the pulley, E. If now the needle goes back, the loop 3 will close the tongue over the thread 2 and pull this through the loop, which then slips from the needle and upon the cord. On the return movement of the needle, the thread 2 will slip over the tongue on the shank of the needle, and the thread 3 passes into the needle and is drawn through the loop 2, and so on.

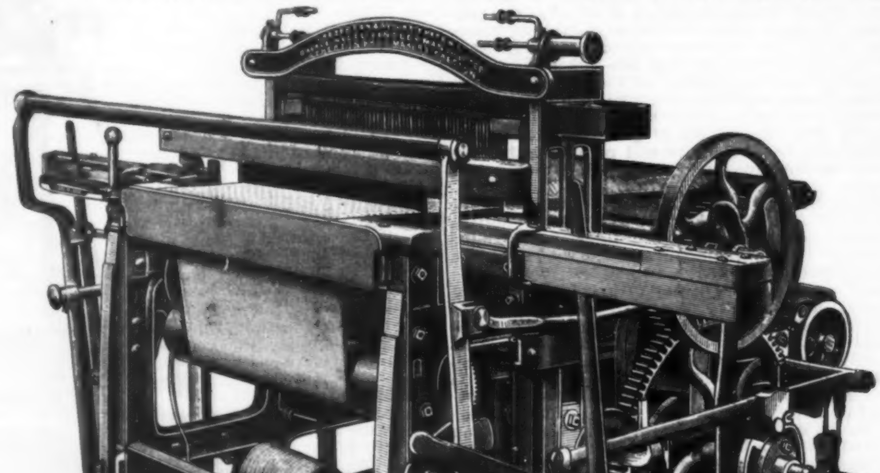
The pattern of the covering threads can be altered by turning the pulley, X, containing the core, or only certain threads may be conducted to the needle, while others pass on without being caught by it, all of which form different designs by the action of the needle.—*Textile Manufacturer.*



MACHINE FOR COVERING CORDS.

THE RUSSIAN SILK LOOM.

In this new design, in all looms up to 40 in. reed space one of the two sets of treadles and lifters has been taken out. The warp pacing motion has been retained, and in the take-up motion the sheaf of catches has been enlarged by the addition of two more, which give a proportionately finer take-up. The shaft of the take-up motion has been detached from the stud and the ratchet wheel, giving it independent action. The stop frogs, which receive the impact of the stop-rod catches, have been supplied with good buffer springs, placed in front of and attached to the loom frame in the usual manner. The ordinary weft-fork stop motion has been introduced, and a neatly constructed and efficient brake, very quick in its action, has been supplied. The picking shafts have had their springs connected by means of a strap, which eases and softens the pick very considerably from its former somewhat harsh state. This strap runs over a carrier pulley on the center rail of the loom. Any stretch in the strap can be adjusted with facility in a minute or two. The leather buffer used in most underpick looms to receive the impact of the picking stick when it has delivered the shuttle has been introduced, and the picking shaft has also been supplied with a buffer, which prevents the bowl of the shaft dropping upon the picking cams, thus greatly diminishing the wear and tear of those parts. The driving pulleys are reversed, the fast one being the outermost of the two. This is owing to the necessity of making provision for the fast pulley actuating the dwell arm. The selvage motion has been simplified and improved, and adapted to put from one to four picks in a single shed, which for many fabrics is an important and necessary arrangement. Provision has also been made for reducing or enlarging the selvage shed to fit it for the passage of a silk or worsted shuttle. A grid has been introduced to insure accuracy in the working of the treadles by the tappet. Provision has also been made for independent warp selvages by the introduction of what are known in the silk trade as anchor bobbins, which contain the selvage warps. The selvage warps are weighted on the same principle as the large warps. The frame of the loom has been strengthened throughout to suit it for being driven by steam or water power, as may be deemed the most expedient. Of course, the new frame has provision for the reception of two warps.



THE RUSSIAN SILK LOOM—IMPROVED.

It can still be used as a hand loom if desired, and as shown in our illustration contains the foot-board, hand-rail, and other parts of the mechanism necessary for operating it by hand. As now arranged, it can also be used for weaving the finest linen cambrics or muslins, and for the former purpose it is being regarded with considerable interest in Belfast as a possible substitute for the hand loom now used extensively in that district for weaving the finest fabrics made in the linen trade. Further information of Atherton Bros., loom makers, Preston.—*Textile Manufacturer.*

CHARNEAU'S HEAT RECUPERATOR.

The large saving in fuel effected through the recuperation of the lost heat of gases proceeding from manufactories has in recent years caused the adoption of certain heating apparatus which are characteristically different from the old style ones. Of all the methods proposed for this purpose, the one that has obtained the strongest foothold in practice consists in a continuous heating of the air necessary for combustion, without any necessity of reversing the currents or of maneuvering dampers.

With this object in view, heat recuperators have been devised for satisfying the following conditions, viz., resistance, without distortion, to variations in temperature; great power under small dimensions; ease of inspection and cleaning, even while operating; and but slight resistance to the motions of the gases

Mr. A. Charneau has devised an apparatus of this nature which is more especially designed to be applied to the furnaces of glass works, and in which he has striven to avoid the use of hollow bricks or special pottery, of which the manufacture might not be all that could be wished, and would thus prove very unsuitable for glass works, on account of the vitrifying substances carried along by the draught of the chimney.

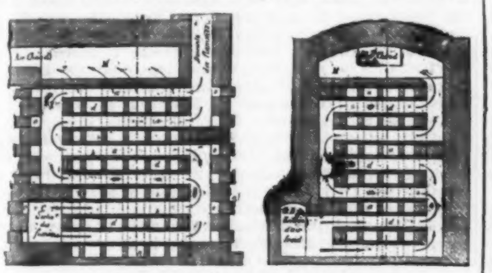
This apparatus, which Mr. Charneau styles a "heat accumulator," is shown in the annexed cut.

It may be constructed of ordinary 9 × 5 × 2 inch bricks, where the furnace is a high temperature one. Fig. 1 gives a vertical section of the accumulator in the direction of the passage of the waste flames of the furnace, and Fig. 2 shows how the air to be heated circulates.

It will be seen that the accumulator consists of a

series of small parallel conduits, *a, a, a*, constructed of bricks of ordinary dimensions, and into which pass the waste flames from the furnace, these circulating through the mass of bricks and then going to the draught chimney through the flue, C. The air to be heated enters through the conduit, B, and penetrates the apparatus through a series of small horizontal conduits, *d, d, d*, that are at right angles with those through which the flames pass. It then becomes heated in rising, enters the hot-air chimney, M, and from thence goes to the burners through one or more conduits. Each stratum of air is enveloped by two strata of flames, and, conversely, each stratum of flames is enveloped by two strata of the air to be heated.

The separation of the flames from the air to be heated is effected through a pavement formed of small flagstones, *k*, or of ordinary brick. By reason of the small conduits being constructed at right angles with each other, the joints are perfectly tight, since they are covered in every direction by a thickness of solid



FIGS. 1 AND 2.—Front and End Sections.

CHARNEAU'S HEAT RECUPERATOR.

bricks. No communication, then, can occur between the strata of flames and those of the air to be heated.

The weight of the mass of bricks is sufficient to secure stability in the apparatus. Moreover, all the conduits are prolonged as far as to the walls of the chamber, and thus form a series of small vertical partitions that abut against the four inner surfaces of the brick masonry, and prevent all tendency to distortion.

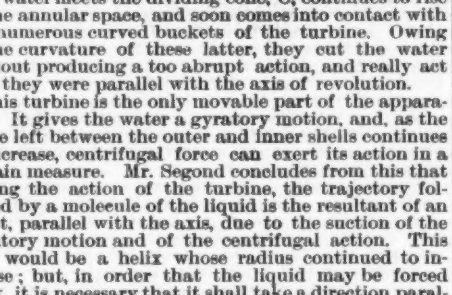
Sight holes, *o, o, o*, are formed in the walls, so that the state of the interior of the accumulator may be examined, and any dust be removed that has accumulated in the smoke conduits. The cleaning may be readily effected while the furnace is in operation. —*Revue Industrielle.*

SEGON'S APPARATUS FOR RAISING WATER.

THE apparatus represented herewith is called by its inventor, Mr. Segond, a "gyro-pulseur," and is designed for setting large bulks of liquids in motion. It may be employed for the same purposes as a pump, and also for propelling vessels through reaction. It consists of an S-shaped shell, E, of a small turbine, N, and of a stationary piece which the inventor calls a "righter."

The lower extremity of E dips into the water, and the latter is sucked up, as will be explained hereafter. The water meets the dividing cone, C, continues to rise in the annular space, and soon comes into contact with the numerous curved buckets of the turbine. Owing to the curvature of these latter, they cut the water without producing a too abrupt action, and really act as if they were parallel with the axis of revolution.

This turbine is the only movable part of the apparatus. It gives the water a gyratory motion, and, as the space left between the outer and inner shells continues to increase, centrifugal force can exert its action in a certain measure. Mr. Segond concludes from this that during the action of the turbine, the trajectory followed by a molecule of the liquid is the resultant of an effect, parallel with the axis, due to the suction of the gyratory motion and of the centrifugal action. This line would be a helix whose radius continued to increase; but, in order that the liquid may be forced back, it is necessary that it shall take a direction parallel with the axis. Such a transformation of motion is effected by means of the device, N', which consists of a ring provided with projections, which form numerous channels in the annular space, A, and through which the water circulates. These appendages are bent at their insertion in order to deaden the shock on the entrance of the streams of water, the primary direction of which is gradually modified until it becomes paral-



SEGOND'S APPARATUS FOR RAISING WATER.

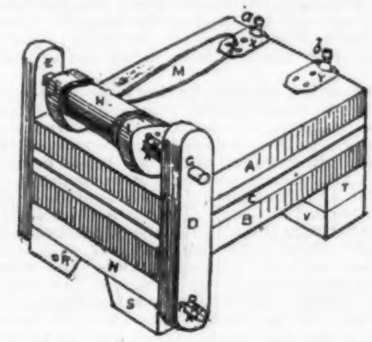
lel with the axis. At this moment there naturally occurs a loss of live force; but the inventor states that with directing channels having polished sides and a proper curvature, the power obtained is sufficient for raising a column of water. On making their exit from the "righter," the streams of liquid unite around the cone, C', and then leave it in order to circulate through the water main.

One of the most remarkable peculiarities of this apparatus is that its operation is based upon the use of but one movable part. This latter is keyed to a steel shaft, which is guided in the shell of the "righter," and is supported externally by a pillow-block, beyond which is the driving pulley. A stopping-box placed at the point where the shaft enters the chamber makes a tight joint, and a foot valve at the lower end of the external shell permits of priming the latter at the start.

The principal parts of the apparatus are of very hard phosphor-bronze, and the others of brass. The apparatus is as yet so new that it has not shown what it can do in practice, but, according to the calculations of the inventor, its performance will reach a pretty high figure.—*Revue Industrielle.*

A CHEAP PRINTING PRESS.

I HAVE used it both for letter-press and lithography, and find it does very good work. A and B, two planks of wood 18 in. × 12 in. × 2 in.; C, wooden plank 18 in. × 12 in. × 1 in.; D, E, two wooden shafts 15 in. × 3 in. × $1\frac{1}{2}$ in.

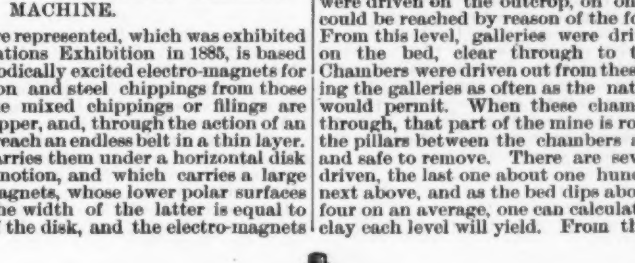


having two holes, each $1\frac{1}{2}$ in. diameter, bored through at A and F and G, 10 in. from center of P to center of G, corresponding holes in E; H is a wooden shaft 4 in. diameter, carrying two eccentric wooden wheels, I and J, $4\frac{1}{2}$ in. diameter and $1\frac{1}{2}$ in thick. These eccentrics are bound with hoop iron $1\frac{1}{2}$ in., and $\frac{1}{16}$ in. thick; so also are the shafts at K and (L). M is a wooden handle let into H, 18 in. long and 2 to 3 in. thick; N is 12 in. × 3 in. × 2 in., and carrying two journals, P, (Q), $1\frac{1}{2}$ in. diameter; R, S, T, (U), V are wooden supports 3 in. wide and 2 in. thick (all screwed to hold together); X, Y are two iron hinges, but made with a slot and screw (as *b*), so as to allow the wooden plank, A, to be screwed up or down. The plank, C, is covered with a sheet of copper (zinc or iron), about $\frac{1}{16}$ in. thick, on which the type ($\frac{11}{12}$ in. high) is laid in the usual way. Under the board, A, are half a dozen thicknesses of blotting-paper; over these, two folds of blanket and one fold of India rubber sheeting (good calico will do instead of sheeting). The frisket is made of $1\frac{1}{4}$ in. hoop iron cut in two, and joined so as to go round A in the usual way, and the press acts on the nutcracker principle; but by having screws at X and Y, besides the usual hinges, and under the eccentrics, I and J, two small pieces of hoop iron, the pressure may be altered at any corner of the plank, A, required. I find that the eccentric gives a good feel of the impression, and the press is cheap, the only expensive part being the hinges, X and Y; the rest is wood, hoop iron, and tin plate.

By taking out the board, C, and substituting a lithographic stone 18 in. × 12 in. × 2 in., good lithographic work can be done.—*J. Knowles, Eng. Mechanic.*

HILDER AND SCOTT'S METAL SORTING MACHINE.

THE apparatus here represented, which was exhibited at the London Inventions Exhibition in 1885, is based upon the use of periodically excited electro-magnets for the separation of iron and steel chippings from those of other metals. The mixed chippings or filings are thrown in a large hopper, and, through the action of an automatic agitator, reach an endless belt in a thin layer. This belt or apron carries them under a horizontal disk which has a rotary motion, and which carries a large number of electro-magnets, whose lower polar surfaces graze the apron. The width of the latter is equal to half the diameter of the disk, and the electro-magnets



HILDER & SCOTT'S METAL SEPARATOR.

above it are excited at this moment by a current from a dynamo which always passes through half of the bobbins of the electros; consequently, the particles of iron are attracted to the polar pieces, while the others, being carried along by the endless apron, fall into a receptacle placed to the left. Upon the second half of the disk the electros cease to be excited, and the iron chippings fall upon a second apron, which carries them along.

The passages and interruptions of the current are regulated by a commutator placed upon the shaft of the disk, and against which rub the brushes that communicate with the dynamo conductors. An apparatus of this kind, with a $4\frac{1}{2}$ foot disk, is capable of separating 2 tons of scrap or ore. In the separator invented and exhibited by H. Kessler at Oberlahnstein, a rotary cast iron drum forms a permanent electro-magnet, which is excited by means of one or two bobbins wound around its circumference, and the wire of which communicates with a dynamo. This drum is supported by brass arms. The mixed scrap is thrown upon an agitator, which leads it against the drum's surface, and the iron adheres to the latter, while the other metals drop. The fragments of iron are afterward detached by the rubbing of a sheet iron wiper against the drum. —*La Lumiere Electrique.*

THE MANUFACTURE OF FIRE-BRICK AT MOUNT SAVAGE, MARYLAND.*

By ROBERT ANDERSON COOK, A.M., Mount Savage.

THE subject of refractory materials occupies such an important position in all metallurgical works, and particularly in those of iron and steel, that any data concerning it must be of interest to the metallurgist. No apology is needed, therefore, for this attempt to describe the mining of fire-clay and the manufacture of fire-brick at one of the largest establishments in this country.

Mount Savage is a small village situated in the northwestern part of the Cumberland coal basin, on the Cumberland & Pennsylvania Railroad, and at the foot of Savage Mountain, from which the village takes its name.

Fire-brick have been manufactured here almost, if not quite, as long as in any place in America; and as the brick are still shipped to nearly half the States in the Union every month, the manufactory is probably the most generally known.

In the year 1837, a company was formed called the Maryland & New York Coal and Iron Company. It built two blast-furnaces, the ruins of which still remain. It was in the construction of these furnaces that the first fire-brick made here were used; and though the iron-works ran but spasmodically, the brick-works have been in constant operation ever since.

From 1837 until 1846 the Maryland Coal and Iron Company, from then until 1848 the Lochiel Iron Company, and from 1848 until 1864 the Mount Savage Iron Company, ran the brick-works and in connection with them the blast-furnaces and extensive rolling-mills. In 1864, the Consolidation Coal Company ran the entire works; and it was not until 1868 that the iron manufactory was given up, with the exception of the foundry. In 1870, the Union Mining Company of Alleghany County was formed, and is now engaged in the manufacture of bricks from the mine that was opened about 1841.

The Clay Mine.—The mine is situated on the south side of Savage Mountain, three miles from the works by the tram-road. The bed of clay crops out along the summit of the mountain, and runs nearly northeast and southwest. The only other mine on this bed is a very small one, two miles southwest from that of the Union Mining Company. The clay from this mine is brought to Frostburg, where it is manufactured into brick.

The large bed was first opened on the outcrop, and for a number of years all the clay was dug from open pits, and hauled at great expense down the mountain in wagons to the works. Finally, when this method of mining had been carried on as long as was economical, the mine began to be worked systematically, and levels were driven on the outcrop, on one side, wherever it could be reached by reason of the formation of the hill. From this level, galleries were driven at an angle up on the bed, clear through to the old workings. Chambers were driven out from these galleries, connecting the galleries as often as the nature of the ground would permit. When these chambers are all driven through, that part of the mine is robbed of as many of the pillars between the chambers as it is practicable and safe to remove. There are several of these levels driven, the last one about one hundred feet below the next above, and as the bed dips about one foot in every four on an average, one can calculate on the amount of clay each level will yield. From the present outlook, there is enough to run the works for a great many years.

At the time this more systematic mining was begun, some cheaper mode of transportation was also sought. First, a wire tram on the English system was tried, consisting of an endless wire rope, with buckets of the capacity of fifty pounds, and a stationary engine of eight horse-power at the bottom. This plan involved much trouble, and never could supply the requisite amount of clay, and when winter came, with its extreme cold and snow, the plant was practically useless. Then the regular three-rail incline was adopted, which is in

* A paper read at the Pittsburg Meeting of the American Institute of Mining Engineers, February, 1886.

common use in this coal region, and which has worked well ever since. The only peculiarity of this incline is its great length. It is a mile and a quarter long, and the rise from the bottom to the top is 1,240 feet. Six cars run upon it at a time; three loaded ones coming down haul up the three empty ones. The rope is of steel, five-eighths of an inch in diameter, and runs over two shive wheels twelve feet in diameter, on each of which is a band brake. One man to run these brakes, two men to load, one man to unhook at the bottom, and one to look after the rollers on the incline, are all that are necessary to run 100 tons of clay a day. The cars when empty weigh 1,800 pounds, and two tons of clay are loaded on each car. It takes seven minutes, on an average, to run one trip. This is said to be the longest gravity road of its kind in the world. From the bottom of this incline, the loaded cars run down by gravity on a tram-road to the brick-yard, and the empty cars are hauled back by mules to the foot of the incline.

The bed of clay lies at the very bottom of the coal measures of this basin. On top of the clay lies an 8-inch bed of coal; beneath it lie from three to four feet of shale; and then comes the conglomerate rock that marks the boundary of this basin. The bed of clay varies from eight to twenty feet in thickness.

The clay is divided into two varieties, the hard and the soft; and these are distinguished by their physical properties. One of these varieties is of a medium gray color, shading almost to black. This clay is very hard, and rattles like crockery when throw into the chutes. It has a distinct, though not regular, conchoidal fracture; it is non-plastic unless ground to an impalpable powder; and does not crumble much when exposed to the weather in heaps, being affected for only about three or four inches from the surface, though exposed for years. In parts of the mine, this clay, when finely broken, is sharp enough to cut one's hands.

The other variety is a very plastic clay of much lighter color, weathering very rapidly, and in one season's exposure crumbling to powder.

The peculiarity of this deposit is that the two clays are so intermixed in the same bed and in such a way that in the present development of the mine there is no accounting for the difference in structure of the clay. In one place, the bed will be full from roof to floor of hard clay; and in another place, within a few feet of the former, the clay will all be soft. These sudden changes cannot be accounted for. Usually the soft clay lies on top of the hard and acts as a sort of protector for it, keeping off the coal-water. In some places, again, there is a gradual change from one to the other, from hard to soft and back again; and often the hard clay lies between layers of the soft. This is what causes the difficulty in the mining work and makes it seem irregular; for where the hard clay is struck, small pillars and large chambers are made, and *vice versa*.

The impurities in this clay are much the same as in all other clays, except that they are fewer and smaller in amount. There are some balls of iron ore found in the bottom of the bed, but these can readily be seen. The most objectionable impurity is iron pyrites, which is found in the slips of the soft clay, and particularly in the casts of roots in that variety. The detection of this iron pyrites is impracticable until after the bricks have been subjected to the intense heat of the kiln, when discoloration is shown in spots on their surfaces.

The coal that is used at the works is obtained on the property from the coal measures above the clay. It is mined from a vein twenty-two inches thick, and is brought down to the head of the tram-road by a short incline, and there it is run in with the clay, and trains made up of both are run down to the brick-yard.

A good many analyses of this clay have been made at various times and by different chemists; but it would not be safe to take any one of the various results as a test, for the difference in them is probably due as much to the chemists as to the samples. The following is an average of several results, which will probably give as accurate an analysis as one could obtain:

Silica	55·75
Alumina	33·23
Impurities	2·06
Water	10·37

The Brick Manufacture.—The plant for carrying on the manufacture of brick here is as complete as can well be found. There is a foundry and a machine-shop where every machine used in the manufacture of the brick is made. The rollers and pans for crushing the clay, the tempering-pans, presses (hand and steam), are all made entirely at the works, so that all varieties of shapes of brick can be made and pressed. The works are complete for turning out all brick, from the smallest nine-inch shape, weighing three pounds, to the largest glass-house shapes, weighing three thousand pounds.

The kilns for calcining the clay are built of brick, with a boiler-iron shell. They are fifteen feet high, and eight feet in diameter, with fire-holes a few feet from the bottom. The top is dome-shaped, with a chimney from the center having a damper on top. The clay is charged in through a hole near the top of the dome, and is drawn out at the bottom of the kiln on iron plates, through two drawing-doors, one on each side of the kiln, twenty tons being the daily product of one kiln.

"The most important constituent is the calcined clay or chamotte. This will not shrink, and possesses the power of union in the greatest possible degree."* These two important qualities have more to do with the production of a brick, regular both in size and in quality, than any other features in the material or process employed.

Another advantage in calcining clay is that it enables one to throw aside any clay in which there are impurities that may have been previously overlooked, since these are much more easily seen when the clay has been burned. The proportion used must, of course, vary with the size of the brick or tile, and the particular use for which it is intended.

From the crushing pan, which consists of two heavy rollers on a revolving grate, the clay goes by an elevator, through the screens, into a hopper above the tempering pan. This pan is on the same principle as that used in crushing, except that, instead of having a grate-bottom, it is of solid iron. The clay is carried to the tables of the various moulders by an endless belt. The brick are all moulded by hand. They are dried on a brick floor, heated by flues running the whole length of the yard. When dry enough, they are pressed in hand-presses unless they are too large. In that case, they are made in a steam-press at first, and smoothed up by hand when dry enough. No machine for moulding is used here, though it was tried at one time with more or less success, but the bricks were never as even and regular as they are now.

After the bricks are moulded, pressed, and thoroughly dried, they are ready for the kilns. The kilns used here are of two varieties. One is the regular down-draught kiln, rectangular in shape, with fire-holes on two sides, and a flue in the bottom, running the whole length of the kiln, having a direct connection with a stack at one end which gives the draught. Breasts of bricks are built in front of the fire-holes to protect the brick nearest the fire from direct contact with the flame.

The other is a gas-kiln, having some of the peculiarities of the Hoffman, in that some solid fuel is used, and also the heat from the burning bricks dries the brick gradually. In these two points, it resembles the Hoffman kiln, but it differs from that in not being a continuous kiln, being rectangular in shape, instead of elliptical, and using gas for its principal fuel. The kiln is two hundred feet long, forming a tunnel with rows of holes through the roof for the admission of the gas and coal. These holes are provided with iron caps, which can easily be removed. Along one side of the kiln is a flue leading to the stack, and flues leading out at right angles to this run across the kiln, so that the gas comes in at the top and goes out at the bottom. At one end of the kiln are fire-holes, and the brick are set at this end first and the kiln set full for a certain distance. Care is taken to leave a clear space under each hopper in the roof, so that the fuel can go to the bottom. Iron plates are used to shut off the brick already in the kilns from the men setting the bricks, and these plates are made tight by smearing them with clay, making of each section a chamber by itself. The fires are lighted, and burn very slowly for a time until the first brick are gradually but thoroughly heated, when some fine coal is dropped in through the roof. The gas is then admitted through the holes in the roof, and the fire-holes are tightly closed, only enough air being admitted through the red-hot bricks for the combustion of the gas.

The gas-producer is on a truck, which runs on a track the full length of the kiln; and as fast as the brick are burned, it is moved along the kiln. As it progresses, the iron plates are drawn out and placed further up the kiln, adding new chambers. The brick are very gradually dried in this way, and a greater heat is developed with less cost in this kiln than in any of the down-draught kilns, which are heated in the ordinary direct way with coal.

This kiln will hold three hundred thousand brick, and it takes thirty days to burn it from end to end. One man and a boy are all that are necessary to run the producer, except when it must be moved.

The combined product of the works amounts to the equivalent of something over twenty thousand nine-inch bricks a day.

The writer has been employed by the Union Mining Company in making such tests as seemed to be desirable to keep the brick up to the best form for any change that might take place in the market. It was not intended that other clays should be bought to mix with those found here; and from tests made here of brick from other places, and calculations from analyses of other clays, it is doubtful whether any could be procured that would be of any advantage in the general run of fire-brick work.

For the calculations in getting at the value of fire-clay from its analysis, the formula used was one given by a German chemist, Dr. Carl Bischof, who is a recognized authority on the subject of refractory materials, and whose investigations on the subject have been carried out and verified to some extent in this country. He divides the clay into two parts, the silica and alumina constituting the refractory part, and the impurities the fluxing part. Dr. Bischof, in this formula, uses the impurities as a whole, but in another he divides them according to their relative strength as fluxing agents.

Taking the alumina divided by the total impurities as a dividend and the result of the silica divided by the alumina as a divisor, the quotient will be a measure of the refractoriness of the clay as compared with that of another clay treated in the same way. Calling RO the impurities, the formula will be as follows:

$$\frac{Al_2O_3}{RO} \div \frac{SiO_2}{Al_2O_3}$$

As small a difference as 0·05 between the quotients thus obtained for two different clays indicates a difference in refractory quality that will show itself, other things being equal, in a furnace test.

These calculations are of great use in comparison of different clays; but the result one might expect from them may be entirely changed when the clays are made into brick. The physical qualities of all clays must be tested before an absolutely perfect comparison can be made. A sample of the same clay being used by two different brick-makers, yet the one brick made from it may not be as refractory as the other, though the sample may have been thoroughly mixed; for if in one case the clay be coarsely and in the other finely ground, the coarse one will stand a great deal more heat than the other before it vitrifies to a homogeneous mass.

This has been often observed before; and the writer has found it perfectly true, as regards this clay, that the more finely it is ground, the less refractory it becomes. At the same time, the more finely it is ground, the stronger and harder the brick becomes, the more abrasion it will stand, and the less likelihood there is of its being broken in handling. Though refractoriness is an essential of fire-brick, yet it is not the only one.

For the various positions in which the brick are placed, and the duties they are expected to perform, from the upper part of a blast-furnace, where the heat is low, and the abrasion of stock is the greatest element in the destruction of the brick, to the ports of an open-hearth steel furnace, where intense heat is the most destructive element, particular mixtures of clay should be made, to get the best results from raw materials.

The greatest trouble of a brick manufacturer is that he cannot be sure for what purpose the brick will be used, or in what position in the furnace they will be placed. Another trouble is, to find out where the fault lies, when complaint is made. This is almost impossible. It may be in the construction of the furnace, or in bad bricklaying, or in the grade of the brick, or that the brick were not hard-burned. And if a sample lot of brick is sent to a mill to be tested, the chances are that, when the superintendent is asked how the brick stood the test, he will have forgotten all about them. The only way for a manufacturer to test the brick is to build a furnace and test them himself, and to do this under as nearly as possible the same conditions as those under which they will be used in practice.

The furnace used by the writer for making such tests had nearly the form of a puddling-furnace. One-half of it was built of one mixture and the other half of another, running through the furnace from end to end. Bridge-wall, roof, side-wall, and neck would show how the brick stood in each position. From the results of the tests, a fair comparison could be obtained of the value of the brick. The draught was a direct one to the foot of a large chimney, and the coal used was a mixture of the best Cumberland coal and our own. A brick of the mixtures used in building the furnace was taken as a standard. One of these bricks, with another, either of some other mixture, or some brick that we wished to test, were placed side by side in the neck of the furnace, which was then fired as hard as possible for a certain length of time. When the furnace had cooled off, the bricks were removed, and the effect carefully noted, particularly as regards shrinkage and vitrification, and the effect of the heat on the furnace was also noticed. The heat in thirty-six hours was intense enough to vitrify any brick, but not enough to destroy them.

As the demand now is for a hard-burned brick, the difficulty of spotted bricks arises. These are bricks that appear to be of poor quality; for though a clay may not contain more than one per cent. of oxide of iron, yet if it is exposed to a great heat, these spots will show; and at present, buyers, with the exception of a few who have learned their value, will not take spotted bricks. All the brick from other places that the writer has tested will, when exposed to our greatest heat, show some spots, although, as they come out of an ordinary kiln, they are free from spots.

The two peculiarities that have made this fire-clay so famous are its freedom from impurities and the fact that it contains such a proportion of silica to the alumina that the brick, after they have been hard-burned, will swell a little instead of shrinking, no matter how much they are heated.

The care that the company has taken in preparing its product for market has borne fruit in the gradual increase of its sales from year to year.

[Continued from SUPPLEMENT, No. 537, page 8573.]

RADII OF CURVATURE GEOMETRICALLY DETERMINED.

By Prof. C. W. MACCORD, Sc.D.

II.

THE law of the motion of a point is often most conveniently expressed indirectly, by defining the motion of some piece which carries the point. Thus, we say that the bar which carries the pencil, in the common elliptic trammel, is pivoted to two blocks which slide in straight slots at right angles to each other; and that the Joy valve gear of a locomotive is operated by a point on the connecting rod, of which one end moves in a circle, the other end in a right line.

The following principles will be found of great use in determining the direction of the motion when thus expressed, as well as in other operations closely connected with our ultimate objects.

The first relates to the simultaneous motions of connected points. A single point may move in any direction and with any velocity; but if it be so connected with another that the distance between the two cannot vary, then the motion of the second point will be to a certain extent restricted. The nature of the restriction may be expressed by saying that the motions of the two points at any one instant must be such that their components along the right line joining the points shall be of the same magnitude and have the same direction. Thus, in Fig. 6, let PO be a rigid wire lying

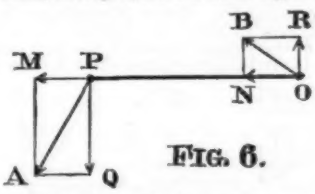


FIG. 6.

and moving in the plane of the paper, and let PA be the motion of P; this may be resolved into the components PM in the direction OP, and PQ perpendicular to OP. And the motion of O at the same instant must be such that its component in the line OP shall be ON, equal to PM, and in the same direction; for otherwise the distance OP would be either increased or diminished, which is contrary to the hypothesis. Should PA be perpendicular to OP, there is no component in that line, and O must either remain at rest or move also in a direction perpendicular to OP, which it is free to do, with any velocity. If, on the other hand, PM be the entire motion of P, then the motion of O must still have, as in the first instance, the component ON; but it may also have a component of any magnitude, as OR, perpendicular to OP, because the line is free to turn about the moving point P as a center.

The second principle relates to the "instantaneous axis of rotation," and may be thus stated: The motion of a right line may, in general, be at any one instant regarded as a rotation about some other right line as an axis; this second line may from instant to instant change its position in space and also its position in relation to the first, whence the term *instantaneous* axis.

Let AB, Fig. 7, represent the motion of the point A. Through A draw an indefinite perpendicular to AB, upon which take any point at pleasure, as C or D, as the center of a circular arc passing through A. Since AB is tangent to this arc, the motion of A is at the

* *Die Feuerfesten Thone*, von Dr. Carl Bischof. Leipzig, 1876, p. 168 (1).

instant the same as one of rotation about the assumed center. Now, applying the same reasoning to each of two moving points of an inextensible right line, as PO, in Fig. 8, it is evident that if we draw through these points, lines XX, YY, respectively, perpendicular to their motions PA, OB, the intersection E of these

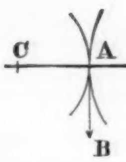


FIG. 7.

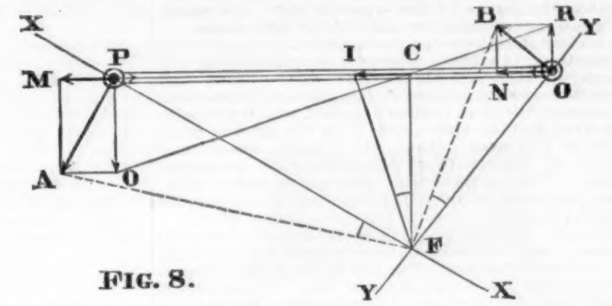


FIG. 8.

perpendiculars will be a common center of rotation at the instant for both P and O, and therefore for the whole line, and indeed for any rigid body of which the line may be conceived to be a part or element; provided that the body be restrained from revolving about the moving line.

Thus the instantaneous center may be found, in general, if the *directions* only of the simultaneous motions of two connected points are known. But if, as in Figs. 9 and 10, these motions are perpendicular to the

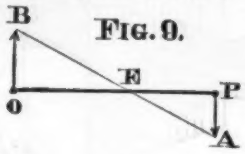


FIG. 9.

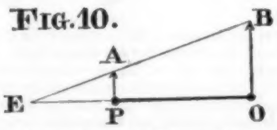


FIG. 10.

moving line, it is necessary to know their relative velocities, as PA, OB. Set these off by any scale of equal parts, and draw AB, which will cut PO or its prolongation in the point E, which is the center sought.

Thus far, the distance between the moving points is considered unchangeable, the moving line being regarded as a rigid link. And it is to be noted that the case of Fig. 8 differs from the two following ones only in the fact that the motion of every point has a component in the line PO. All these components must be equal and in the same direction; and the actual motion of the line may be regarded as the resultant of a rotation about some center in the line itself, combined with a bodily motion of the line endlong. Thus, PQ and OR, by themselves, would, as just shown, establish a rotation about C; now if with PQ we combine PM, the resultant motion of P becomes PA; an equal component ON, with OR, gives the resultant OB, and we have seen that these two resultants may be regarded as rotations about E. But C must now also have an actual motion, CS, equal to PM, which may be regarded as a rotation about some center in CZ perpendicular to OP, which perpendicular will therefore pass through E. This last may be proved by the geometrical construction, since, regarding E as the intersection of CZ with either XX or YY, and drawing BE, LE, AE, we shall have, from similar triangles, and the equality of PM, AQ, ON, BR, LC, the values:

$$\frac{LC}{CE}=\frac{BR}{CE}=\frac{BO}{OE},$$

or

$$\frac{LC}{CE}=\frac{AQ}{CE}=\frac{AP}{PE},$$

therefore the angles AEP, LEC, BEO, which represent the angular velocities of the points P, C, O, in rotating about E, are equal.

The fact that CZ passes through E is often of service in locating that point with precision, since XX and YY may make a very acute angle with each other.

If the motions of the two points are in parallel directions not perpendicular to the line, as in Fig. 11,

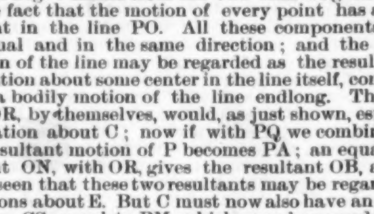


FIG. 11.

the perpendiculars to these motions will be parallel, and the instantaneous center at an infinite distance. In this case the actual linear velocities must be equal, and all the points of the line moving in parallel directions with the same velocity, the motion is one of translation. This is also true, if motions are coincident with or perpendicular to the line itself; the condition of translation is determined by the equality and parallelism of the motions of all the points, independently of the direction, and all three of these different relations are exhibited in the familiar movement of the side rod of a locomotive during a revolution of the driving wheels.

But, now, it is not necessary that the points of a moving right line shall always retain the same relative positions; a line may be supposed inflexible, without being inextensible or incompressible. Thus, a thin elastic cord may remain straight while moving into various positions, while at the same time it may be stretched or allowed to contract, and that unequally in different parts.

In this case the motions of any points of the cord are precisely like those of so many beads sliding on a rigid wire; and if this endlong sliding be their only motion, the wire, evidently, will not change its position in space.

But, recollecting that all movements here considered are in the same plane, let us assign to any two beads, selected at pleasure, motions whose components perpendicular to the wire are equal to each other and have the same direction. Then the wire itself will obviously receive a motion of translation in the direction of these components, and all the beads upon it, however they may move to and fro along the wire, must move sidewise with it at the same rate.

If, however, these perpendicular components be unequal in magnitude or opposite in direction, as shown in Fig. 12, the result will be to produce at the instant

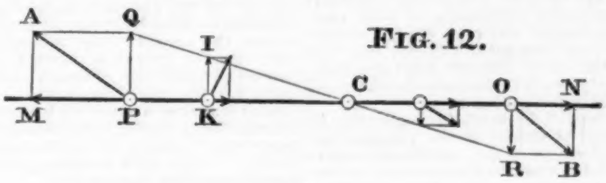


FIG. 12.

a rotation of the wire about a center C upon its axis; PA and OB representing the actual motions of the two beads, the longitudinal components PM, ON, do not tend to move the wire because the beads are free to slide along it, and the effect of the normal components PQ, OR, is exactly the same as in the case of the inextensible line in Figs. 8, 9, and 10. Therefore the point C is found at the intersection of PO with QR; and a bead situated at the point, although at the instant it may be sliding along the wire, can have no component motion perpendicular to it. Also, the normal components of the motions of any other beads, as H, K, will be directly proportional to their distances from C; since from similar triangles we have:

$$\frac{KL}{PQ}=\frac{CK}{CP}=\frac{HG}{CH}=\frac{OR}{CO}$$

Of course, such an elastic cord may at any instant be revolving about an instantaneous axis, just as well as the inextensible wire previously considered; but neither that fact, nor the location of that axis, can be determined from a knowledge of the motions of any points upon it, of which the components along the line differ, either in magnitude or in direction, from the actual motion at the same instant of the point C, which, as we have seen, can have no side component.

Now, it was shown in the preceding article, that if a right line move in space, subject to the condition that it shall be always normal to a given fixed curve, it is at every instant tangent to another fixed curve, the evolute of the first, and is at any one instant rotating about the point of tangency, which is the center of curvature of the involute at the point of normalcy.

If then we can determine the simultaneous motions of any two points upon the normal line, we have merely to find the components perpendicular to that line, in order to locate this center of rotation.

In applying this process for determining the radius of curvature in any given case, we have then first of all to consider how the two simultaneous motions just mentioned are to be ascertained. For this no specific rule of general application can be given; as in many other geometrical investigations, special constructions must often be devised for individual cases, and much depends upon the ingenuity of the investigator. But in a rather indefinite way, it may be said that the determination of these two motions will often be facilitated by regarding the given curve as the path of a point controlled by mechanical devices. The motion of the generating point, and of some other point upon the normal, may then, upon an examination of the movements of the various parts of the combination, be found capable of determination by the aid of the principles relating to the composition and resolution of motion, the motion of connected points, and the instantaneous axis of rotation, briefly explained in this article. The latter in particular will be found serviceable, notably because the instantaneous center of a rigid piece is itself a point in the normal to the path of any point carried by that piece; so that, if we are able to determine the path of that axis during the operation of the mechanism, and its rate as compared with that of the generating point at any instant, our object is accomplished. And in the succeeding articles we propose to illustrate by a number of examples the manner in which the mode of operation thus indicated may be practically employed.

THE PHOTOMETER.

AT a recent meeting of the Berlin Physical Society, Dr. Konig spoke of some photometers he had quite recently tested in respect of their precision. The simple Bunsen photometer, consisting of a screen of fine writing paper smeared with a grease spot, labored under the drawback that it was not possible to contemplate simultaneously the two sides it was desired to compare. There were several modifications of this apparatus planned with a view to overcoming this defect. First, there was the application of two mirrors inclined at 45°, by means of which both surfaces were seen in juxtaposition. Other contrivances for the same purpose were the application of a prism, the edge of which lay in the plane of the screen; the use of two prisms; and, further, the use of two totally reflecting prisms with lenses. The last named description of photometer, as also the mirror-photometer, was very exact, but it now appeared that it was not possible to cause the spot of grease wholly to vanish from view. For such precise photometers there would, on the contrary, have to be found two substances which reflected and transmitted the light differently, but yet absorbed it with equal strength and possessed the same structure. Weber's photometer was constructed according to an entirely different principle. It consisted in the main of a small benzine lamp, which was placed in a tube in front of a mirror and which illumined a milk-glass plate displaceable in the tube. From the illumined milk-glass the light was carried to a totally reflecting prism, and thence into the eyepiece, where it lighted up the half of the field of vision. The other half received light from a milk-glass plate standing in the direction of the eyepiece behind the prism. This milk-glass plate was illumined by the light which was to be measured. In the case of like colored light the registrations of the Weber photometer were very exact, but in the case of different colored lights such precision was not obtained. Of the means employed by Herr Weber to measure different colored lights with his photometer, that which consisted in bringing first a red, then a green, and thereafter a blue glass before the eyepiece, and taking the average of the three measurements, was still at this day the most approximately exact, but was yet inadequate. A great advantage belonging to the Weber photometer, on the other hand, was that by means of it the scattered daylight could be measured. The readily available Weber photometer would prove itself particularly useful for the purpose of testing the conditions of illumination in school-rooms.

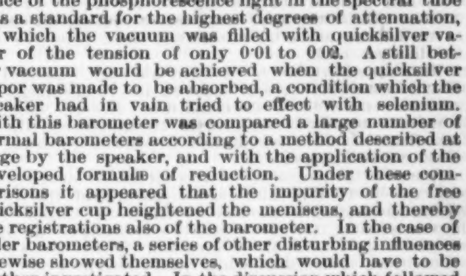
THE BAROMETER.

Dr. Grunmach reported on the barometric investigations carried out by him in the Normal Gauging Office. He described at length the arrangement of the normal barometer, the vacuum of which was measured in an electrical way. A combination of the barometer vacuum with a Geissler tube permitted the attenuation to be examined even beyond the limits of the pressures measurable by the cathetometer. The occurrence of the phosphorescence light in the spectral tube was a standard for the highest degrees of attenuation, in which the vacuum was filled with quicksilver vapor of the tension of only 0·01 to 0·02. A still better vacuum would be achieved when the quicksilver vapor was made to be absorbed, a condition which the speaker had in vain tried to effect with selenium. With this barometer was compared a large number of normal barometers according to a method described at large by the speaker, and with the application of the developed formulæ of reduction. Under these comparisons it appeared that the impurity of the free quicksilver cup heightened the meniscus, and thereby the registrations also of the barometer. In the case of older barometers, a series of other disturbing influences likewise showed themselves, which would have to be further investigated. In the discussion which followed this address, Dr. Goldstein proposed for the electrical measurement of the vacuum, instead of Geissler's spectral tube, the employment of a wide tube which let the fluorescence light pass more obviously into the phenomenon; and for the graduations of these highest degrees of attenuation the thermometer would, he maintained, be better adapted than were the optical phenomena. Let, namely, a thermometer be brought into a vacuum tube whose positive pole was a point, but whose negative electrode was a steel plate nearly filling out the tube in front of the cathode; then the thermometer, when the attenuation reached such a degree that the cathode light appeared, would mount 80° to 90° above the temperature of the room. At the positive pole the thermometer rose only about 3°. This rise of temperature in the cathode light occurred in connection with the degree of attenuation, and might be utilized for the measurement of these degrees.

EXPLANATION OF THE MAXWELL ELECTRO-MAGNETIC THEORY OF LIGHT.

MISS J. M. CHAMBERS, B.S., has lately pointed out a graphic process which well explains the electro-magnetic theory of light established by the late Clerk Maxwell.

In the annexed figure, AB represents a straight con-



ductor into which is passing an undulatory electric current. The lines of magnetic force resulting from this latter will form circles, all of which have the conductor as an axis.

Let us imagine a series of such conductors parallel with one another, AB, ba, a′ b′, etc. When the lines of force from A B intersect the neighboring conductor, ba, there will occur, according to Lenz's law, an electromotive force of a sign contrary to that of which A B is the seat; and ab will be traversed by a current which, in its turn, will be surrounded by lines of magnetic force.

If we reverse the current at AB, the induced current at *ba* will likewise be reversed. The action of *ba* upon *a' b'* will be the same as that of AB upon *ba*, and the effect will be propagated upon the entire line of molecules.

Electromotive and magnetic forces, then, act in directions at right angles, not only to each other, but also to the line of propagation, OX, this being conformable with theory.

This explanation applies to light polarized in a plane, and gives a very clear idea of the manner in which occur those "series of magnetizations and of electromotive forces of opposite directions" that we meet with in Clerk Maxwell's theory.—*La Lumiere Electrique.*

POLARIZED LIGHT.*

By GEORGE M. HOPKINS.

LIGHT, so abundant, so free, so necessary in the economy of nature, so regularly and uniformly supplied, is regarded as a matter of course, and not one in ten thousand of the recipients of its benefits ever thinks of its mysterious nature, or attempts in any way to investigate its phenomena. But for the discoveries and deductions of such men as Newton, Huygens, Malus, Brewster, Fresnel, and Young, we of the present day might have remained in utter darkness as regards the nature of light.

To the photographer, the study of light is vital; and to the amateur, it should become an object of systematic study and experimental investigation.

Working on the negative principle, so common in human affairs, we shall not examine light in its bearings on photography, neither shall we deal to any considerable extent with elementary principles, or with phenomena which in the logical order of things should come first in the study of this great subject, but will with one dash enter the most difficult, least generally understood, and most theory beleaguered branch of this study, viz., that of polarized light.

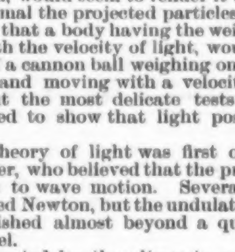
However, we must halt a little at the beginning, to briefly review the accepted theory of the propagation of light, and the effect of some substances upon ordinary white light, before we shall be able to undertake our inquiry into the intricate and almost baffling subject of polarized light.

The emission theory, or corpuscular theory of light, was supported by Newton. It supposes light to consist of exceedingly small particles, projected with enormous velocity from a luminous body. Although this theory seems to have support in many of the phenomena of light, the velocity of light alone, as at present recognized, would seem to render it untenable, however infinitesimal the projected particles might be. Tyndall has said that a body having the weight of one grain, moving with the velocity of light, would possess the momentum of a cannon ball weighing one hundred and fifty pounds and moving with a velocity of 1,000 feet a second; but the most delicate tests known to science have failed to show that light possesses any mechanical force.

The emission theory of light was first opposed by Huygens and Euler, who believed that the propagation of light was due to wave motion. Several eminent scientists supported Newton, but the undulatory theory was finally established almost beyond a question, by Young and Fresnel.

Sound is propagated by the alternate compression and rarefaction of air, the movements of the waves being parallel with the line of travel of sound. But not so with light. The vibrations of light are at right angles with its line of progression. These transverse vibrations, in ordinary white light, are in every conceivable direction across the path of the light beam. Their course is represented diagramatically by the figure now on the screen. We can readily see how the longitudinal vibrations of air would affect the ear drum. Fig. 2 shows this action diagramatically, the horizontal

Fig. 1



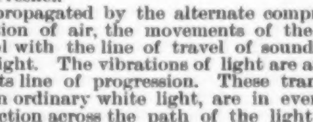


Fig. 2 A Fig. 3 B

line, A, representing the tympanum, and the two arrows the forward and backward motion of the air wave.

The retina, to be affected by the transverse motion of the particles, must in some way be rendered sensitive to such a vibration. Comparatively recent microscopical research has shown that the retina is studded with fine rods, as shown at B, Fig. 3, which are supposed to be susceptible of being influenced by the lateral movements of the particles in the wave front of a light beam.

The difference between sound waves and light waves may perhaps be best illustrated by two simple experiments, the first of which consists in passing in front of a narrow slit a plate traversed by longitudinal wave lines alternately approaching and receding from each other. The gathering together of the light dots represents the compression of the air at the wave front, followed immediately by a separation of the dots, representing the rarefaction of the air between the crests of the waves, then by a return of the dots to the point of starting, and so on, the motion of the point of greatest compression being continuously progressive in one direction, while the air particles themselves, represented by the light dots, make limited excursions which are confined to the length of the slit.

To represent in a crude way the transverse vibrations of light, a sinuous slit is moved behind a grating. Series of light dots are thus produced, which move up and down as the sinuous slit is drawn along. While each dot is confined to a vertical path, the line formed by the series of dots exhibits wave crests and hollows, and the waves move continuously forward. By moving the glass rapidly, the persistence of vision enables us to see the paths of the separate dots, as straight luminous lines crossing the path of the light beam.

It is clear that there can be no vibration except there be something to vibrate; wherever there is motion, it is self-evident that something must move. This fact necessitates the assumption of the existence of a medium far more subtile than ordinary matter, which pervades all matter and all space, and is in the interior of all bodies of whatever nature. It is light, elastic, and capable of transmitting vibrations with enormous velocity. This hypothetical medium is called *ether*. Every luminous body is in a state of vibration, and communicates vibrations to the surrounding ether.

Although light is propagated in straight lines, its direction may be changed by reflection, by any body that will not absorb it. The reflection of light from a mirror is a well known example of this. The direction of light may also be changed by refraction, by allowing it to pass from one medium to another having a different density. By holding a strip of plate glass obliquely before the slit in the lantern, the change of direction of the light is shown by the lateral displacement of a portion of the beam of light on the screen.

Glass, like all uncrystallized bodies, is said to be single refracting, because it diverts the ray in one direction only. By placing a rhomb of Iceland spar before a small aperture in front of the lantern, two images of the aperture appear on the screen, showing that the beam of light has been split up into two. One is called the ordinary ray, the other the extraordinary ray. As the rhomb is turned, the extraordinary ray moves around the ordinary one. This property of splitting the ray transmitted through the crystal, which was first noticed and commented on by Erasmus Bartholinias, in 1669, is known as double refraction. It is possessed by many crystalline bodies in a greater or less degree. Both rays emerging from the spar have acquired peculiar properties.

Newton, after investigating the properties acquired by light in its passage through the spar, concluded that the particles had acquired characteristics analogous to those of magnetized bodies, that is, they had become two sided, and were, in fact, polarized.

Light, in the state of two sidedness as observed by Newton, is still known as polarized light. By inserting the double refracting crystal known as tourmaline between the rhomb of spar and the screen, and turning it, the ordinary and extraordinary rays will be extinguished and will reappear in alternation. All vibrations, except those executed parallel with the axis of the tourmaline, are quenched.

To render these effects visible, a Nicol prism (which will be described later) is now inserted between the rhomb and the screen, as a superior substitute for the tourmaline. By turning the Nicol, the light spots produced by the two rays become alternately visible and invisible. One-quarter of a revolution of the prism is sufficient to extinguish one ray, and bring the other out; and a further turning of the prism through another quarter of a revolution reproduces the extinguished light spot and effaces the visible one. This experiment shows that the vibrations of the two rays are in planes at right angles to each other. A beam of light in which all of the transverse vibrations are parallel with a single plane is plane polarized. Both of the beams emerging from the spar are therefore plane polarized, but in different planes.

The course of the light through the rhomb of Iceland spar when the incident ray is perpendicular to one of the faces of the crystal is shown in the diagram, Fig. 4,

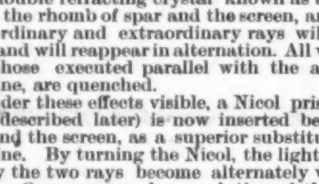


Fig. 4.

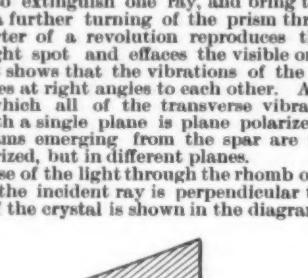


Fig. 5.

upon the screen. The ordinary ray, A, passes straight through the crystal, while the extraordinary ray is bent away from the ordinary ray, on the line, B.

When the incident ray enters the side of the rhomb at an angle (as shown in Fig. 5), the ordinary ray follows the law of refraction, and the extraordinary ray is bent away from the ordinary ray, as in the other case.

The most complete instrument for polarizing light and analyzing it after its polarization is the Nicol prism, made from a rhomb of Iceland spar, and named after its inventor. In this prism, the ordinary ray is disposed of, and the extraordinary ray alone is used.

The prism which is shown in the diagram (Fig. 6), on the screen, consists of a rhomb of Iceland spar, divided through its axis on the line, D D, with its ends cut off at right angles to this line. The two halves of the prism are cemented together by Canada balsam, whose index is between that of the two indices of the spar, so that the ordinary ray, B C', meets the film of balsam at an angle which is sufficiently oblique to secure the reflection of this ray to one side, where it is lost, while the extraordinary ray, B C, passes through the balsam, and onward through the other half of the prism in a perfectly polarized condition.

To observe the effects of polarization, an analyzer is required. Anything that will act as a polarizer will also serve as an analyzer, and as the Nicol prism is unsurpassed as a polarizer, it will answer equally as well as an analyzer.

Fig. 6.

Perhaps the action of polarized light cannot be better illustrated than by a representation of a hypothetical beam of light and two tourmaline plates (Fig. 7).

Fig 7.

Here is shown the beam of light with vibrations traversing the path of the beam in two directions. On reaching the first tourmaline plate, those vibrations which are parallel with the axis of the tourmaline crystal (represented by the parallel lines) are readily transmitted, but all the vibrations in any other direction are extinguished. The beam now polarized passes on to the second tourmaline plate, and the axis of the crystal being arranged at right angles with the plane of vibration, it is extinguished; but if the axis of the second tourmaline is parallel with the plane of vibration, the light will pass through.

If the axes of the tourmalines are arranged at an angle of 45° with each other, the light is only partly extinguished. These effects of the two tourmaline plates are illustrated by the diagrams, Fig. 8 showing

Fig. 8. Fig. 9. Fig. 10.

the crystals with their axes arranged parallel with each other, Fig. 9 showing them arranged at an angle of 45°, and Fig. 10 showing them crossed or arranged at right angles with each other, exhibiting a complete extinction of the ray at the intersection of the crystals.

If, now, when the polarizer and analyzer cross, a double refracting crystal be inserted between the polarizer and analyzer, the light will be more or less polarized, and caused to again vibrate in different planes.

It is evident that when light vibrations are executed in unison (if such an expression may be used), as when the beam is polarized, no interference can occur, and consequently no colors appear, so long as the light is polarized; but when it is depolarized by a crystal or film thin enough to give rise to interference, gorgeous colors will appear. Examples of this will presently be shown.

Besides those means of polarizing light already described, there are others which should be examined. Light is polarized by reflection at the proper angle from almost every object; glass, water, wood, the floating dust of the air, all under certain conditions will polarize light.

That the light beam becomes polarized may be readily ascertained by receiving it through a depolarizing body and an analyzer.

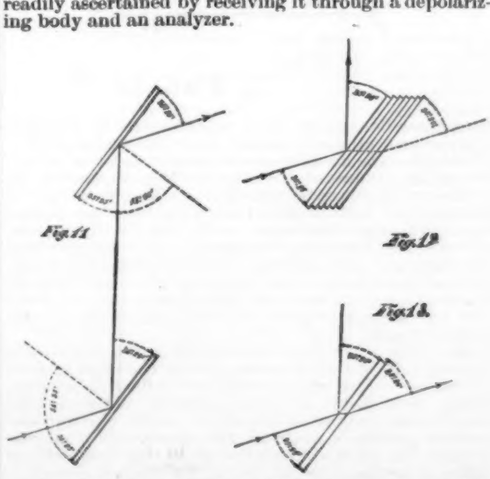


Fig. 11 Fig. 12 Fig. 13.

A few days since, while passing one of the ponds in Prospect Park, at about four o'clock in the afternoon, I observed that the light reflected by the surface of the

* Read before the Society of Amateur Photographers of New York, March 23, 1886.

pond was polarized. A little later, I examined the light reflected by an aquarium and various articles of furniture in my library, among which were a leather covered chair and a black carpet, all of which exhibited the phenomenon to a marked degree, the leather chair covering being the best polarizer.

Two plates of unsilvered glass, receiving and reflecting light (as indicated in Fig. 11), act respectively as polarizer and analyzer.

A series of thin plates, Fig. 12, used in the same way, exhibit it in a marked degree. These plates will also act in a similar manner when the light is transmitted through them, a part of the light in each of these cases being reflected and a part transmitted, both the reflected and transmitted beam being polarized, but in planes at right angles to each other. A single black glass plate is a good polarizer, but a bundle of glass plates backed by black is perhaps better. The arrangement of the polarizing and analyzing prisms with reference to the object to be examined is shown in Fig. 14, and the simple arrangement shown in Fig.

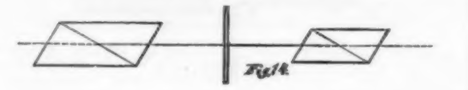


Fig. 14.

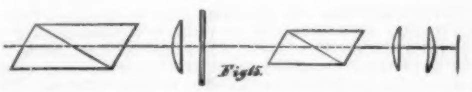


Fig. 15.

15 is the one employed for most of the experiments to follow.

The beam of polarized light may be depolarized by a body which will produce no color, but will simply render the field light when the polarizer and analyzer are crossed (as shown by the insertion of this rather thick piece of mica).

By placing thin pieces of mica in the same position, various colors are produced. When the polarized beam encounters the thin mica, it is resolved into two others at right angles to each other, the waves of one being retarded with reference to the other; but as long as these rays vibrate at right angles to each other, they cannot interfere. The analyzer reduces these vibrations to the same plane, and renders visible the effects of interference due to the retardation of the waves of one part of the beam. The thick plate of mica gave no color, because the different colors were superposed and blended together, forming white light.

In a slice of Iceland spar cut at right angles to the axis of the crystal, the ray is not divided as it is when the light passes in any other direction through the crystal, and if the slice be placed in a parallel beam of polarized light, no marked effect is produced; but when the beam is rendered convergent, by a lens interposed between the polarizer and the crystal, beautiful interference phenomena are developed.

When the polarizer and analyzer are crossed, a system of colored rings intersected by a black cross appears.

The arms of the cross are parallel with the planes of the polarizer and analyzer. On these lines no light can pass, but between them, the colors of the rings increase in intensity toward the middle of the quadrants inclosed by the arms where the interference is most marked. Turning the polarizer or analyzer causes complementary colors to change places, and brings out a white cross instead of the dark one.

By inserting the bundle of glass plates as an analyzer, polarization by both reflection and refraction may be shown. The image projected on the ceiling is complementary to that shown on the screen, and the effects in the two images will be exchanged for complementary effects when the polarizer is turned through a quarter of a revolution.

A plate of selenite, which in the polarized beam produces blue on the screen, exhibits yellow on the ceiling; a plate yielding green on the screen shows red on the ceiling, and again turning the polarizer causes the complementary colors to exchange places.

A crystal of niter, which is one of the class of biaxial crystals, exhibits two centers of rotation. Sugar exhibits two centers with one pair of brushes in each; a quartz crystal disperses the light so widely, that with the present apparatus it cannot be exhibited as a whole, but splendid bands of color appear.

Proceeding to the examination of microscopic crystals and other objects, I will exhibit them by polarized light in succession, simply giving their names:

Cane sugar.
Salicine.
Salicine, with half the crystals backed by mica, to show rotation reversed by the mica.
Santonine, with selenite.
Kinate of quinia.
Asparagin.
Aspartate of cinchonidine.
Stearic acid.
Lithic acid.
Boracic acid.
Tartaric acid.
Benzoic acid.
Sulphate of copper and magnesia.
Sulphate of ammonia and magnesia.
Sulphate of ammonia and iron.
Platino-cyanide of magnesium.
Platino-cyanide of barium.
Platino-cyanide of yttria.
Chloride of barium.
Rhodizite.
Granite.
Fish scales.
Palate of limpet.

[It should be stated that a special screen made of thick pearl-white tracing paper, secured to a common wood hoop four feet in diameter, by mucilage or flour paste, was used. The audience viewed the illustrations by transmitted light, and it was noticed that the delicate colors came out very perfectly on the paper screen, which was accounted for by the fact that no light was lost. The various changing kaleidoscopic hues that appeared as the different chemicals were projected on the screen were very attractive and pleasing to those present.—PRES. SOC. OF AM. PHOTO.]

FUSION BY ELECTRICITY.

By A. M. TANNER.*

SINCE the remarkable discovery by Davy, who was the first to succeed in melting a refractory substance by placing it between two carbon electrodes, a large number of inventors and scientists have endeavored to apply to the fusion of metals the heat that may be obtained through the passage of an electric current.

Mr. Grove, an English physicist, proposed to use for this purpose the current from a battery composed of a large number of elements, and devised the arrangement shown in Fig. 1. The metal is placed in a car-

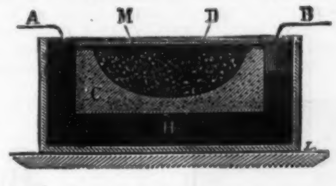


FIG. 1.—GROVE'S ELECTRIC CRUCIBLE.

bon crucible, C, which enters a box filled with mercury, H, and is covered with a plate of carbon, D. The mercury communicates with one of the terminals of the battery, and the cover of the crucible with the other. In this process, the crucible as well as the cover is soon raised to incandescence, and this is what brings about a fusion of the metal, M. This is probably the first application that was ever made of incandescence for fusing metals by electricity.

Count Du Moncel, in his treatise on the Applications of Electricity (vol. iii., p. 316), mentions the use of the calorific effects that may be produced with the electric current for fusing platinum, iridium, osmium, etc., the operation being performed in a crucible of retort carbon.

The apparatus that most nearly approaches the well-known Siemens electric crucible is probably the one which was patented in France by Pichon, March 16, 1853, and which is described in Dingler's Journal, vol. cxxxi., p. 415.

The principle of this apparatus is shown in Fig. 2. Mr. Pichon proposes to have a continuous fall of ore,

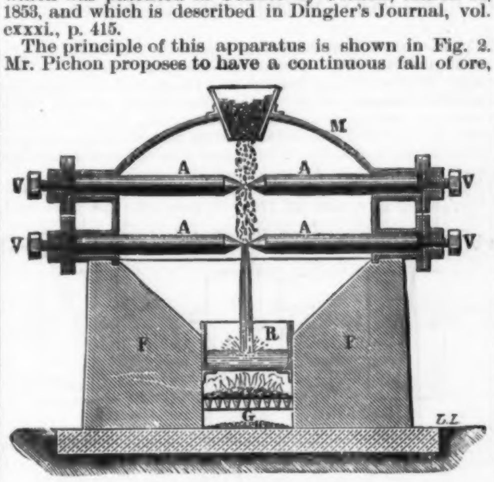


FIG. 2.—SIEMENS' ELECTRIC CRUCIBLE.

mixed with fragments of carbon, between electrodes, A, placed within the crucible and connected with a battery. The molten metal is received in a reservoir, R, heated to a high temperature, so as to keep the metal in a state of fusion. Each electrode is provided with a regulating screw, V. Among French savants and physicists, Despretz and Dumas have more particularly occupied themselves with a study of the calorific effects of electric currents, and have endeavored to determine the laws that regulate such actions. They have been less fortunate in these researches than Prof. Joule, who has connected his name with one of the most important laws of this branch of physics. Every one knows Joule's law, but what is less known is that Prof. Joule, in concert with Prof. Thomson, has performed a large number of experiments for the purpose of discovering an industrial process for the electric fusion of metals.

In an article published in 1856, in the Proceedings of the Literary and Philosophical Society of Manchester (vol. xiv., p. 49), Sir William Thomson asserts that, by passing a strong electric current through a bundle of iron wires surrounded by charcoal, he has melted a portion of the bundle.

Later on, Joule performed a series of analogous experiments, in which he placed wires in the center of glass tubes filled with charcoal or any other bad conductor of heat.

In the article above cited, Thomson also asserts that, with a Daniell pile of six elements, he has succeeded in melting together wires of brass, steel, platinum, iron, etc. He observes, moreover, that the most economical process of fusion would consist in employing the current from a dynamo machine.

Joule has studied the question of fusion by electricity very profoundly and in all its relations, and has reached the conclusion that the double conversion of heat into electricity, and *vice versa*, would not be too costly in view of the results that it is hoped to obtain. In reasoning in this wise he has placed himself upon the same footing with such inventors and modern writers as have treated of the matter. Yet it must be recognized from an industrial point of view, that he has not taken a step forward in the question.

The honor of the first important progress made in this direction is due to Sir William Siemens, and dates back to 1878, the epoch at which he exhibited his first electric crucible. This apparatus has so often been described, and is so well known to all, that I believe it useless to give a new description of it in this place. Nevertheless, I believe it of interest to recall the fact that, almost at the same time that Siemens did, Mr. C. A. Faure took out a patent for an electric crucible of his invention, and claimed therein the industrial application of the heat developed by the electric arc, or by the passage of an electric current, for the reduction of alkaline metals or a combination thereof.

A certain Mr. Fox, likewise, took out an English patent in 1878 for an apparatus of the same sort. His device is a circular crucible internally lined with a bad conductor, such as carbon (preferably in the form of graphite) mixed with refractory clay or some like substance. Upon raising this lining to incandescence through the passage of an internal current, a high enough temperature is obtained in the crucible to melt the metals it contains.

At this same period (1878), Messrs. Lontin and Bertin, too, devised an apparatus for the fusion of refractory bodies. They propose a series of electrodes, circularly arranged and abutting against a block of carbon, in the center of which are placed the materials to be melted. In this way a very high temperature is obtained.

In 1881, the Compagnie Generale Belge de Lumiere Electrique constructed an electric crucible, and used as a refractory substance a mixture of magnesia and oxide of iron. The crucible was invested with a metallic jacket that permitted of the passage of movable electrodes, between which an electric arc formed.

The electric crucible of the Cowles Company, of Cleveland, Ohio, has been much spoken of, and there is reason to believe that this system is better than any other that has hitherto been offered to the public.

In the process used by this house, carbon is mixed with the ore to be reduced, and the latter is inclosed in a non-conducting jacket. The process is chiefly applied to the manufacture of aluminum bronze, and for the fusion of precious metals. It is not very probable that it will ever be applied to common metals.

To sum up, we may say that the question of fusion by electricity is still in its infancy; but it is attracting the attention of engineers, and the time is probably not far distant when dynamos and motors will be sufficiently improved to make the electric crucible a valuable, and even an indispensable, agent for metallurgical operations.

* In *La Lumiere Electrique*.

APPLICATION OF ELECTRICITY TO THE STUDY OF SPONTANEOUS MOTION IN CAPILLARY TUBES.

WHEN into a very fluid liquid (pure water, for example) we plunge the extremity of an open capillary tube that has previously been wet with the liquid, the latter will rise therein with great velocity; but such velocity will slacken in measure as the liquid approaches its final level, which latter, in very narrow tubes, it will reach with exceeding slowness. It is this spontaneous ascensional motion that I propose to study by applying to the experiments that make it manifest an electric process that I have used for controlling and definitely fixing the results obtained by means that I have heretofore described.

Of the numerous analysts and physicists who have treated of capillary phenomena, some have striven to theoretically account for the distortion of liquid surfaces in contact with solids, and for the ascent or depression of such liquids in narrow spaces, while others have endeavored to measure experimentally, and with accuracy, the heights of various liquids corresponding to definite intervals and for known temperatures, that is to say, to discover the general conditions and the results of a phenomenon which comes to an end when equilibrium is restored. But none of them has paid any attention to the *velocity* in a spontaneous ascending motion of liquids in very narrow spaces, under the sole action of the molecular forces that are exerted between the solid and the liquid without the use of any artificial external pressure. In a word, capillarity in this respect has been examined merely from a *static* point of view.

I propose to study the question from a *dynamic* standpoint; that is to say, to determine the nature of the motion in the various phases of the phenomenon, or, in other words, to find out, experimentally and theoretically, the relations that exist between space and time in the motion, as well as between velocity and time, and to trace the curves representing the said motion in different liquids rising in tubes of different diameters, at different inclinations, and at various temperatures.

It has seemed to me that a consideration of this velocity might, by introducing a new element into the question of capillarity, throw some light upon the general conditions of the phenomenon.

In a memoir concerning some experiments that I performed in 1872 on the spontaneous motion of liquids in capillary tubes, I said that we might be able to have recourse to electricity as a means of instantaneously closing a tube, although up to then I had not employed that process. This is the means that I have recently used, and that I now desire to describe, and, at the same time, make known the principal results that it has clearly and surely confirmed.

I shall, in the first place, remark that in all experiments relative to the spontaneous ascent of liquids in capillary tubes, there is, in reality, but one delicate measurement to be effected, and this is that of the length of the liquid column raised by capillary force within a definite time. But such a measurement is very difficult, considering the circumstances under which it must be made. In fact, if it is difficult to estimate with accuracy the height of the fixed level of a liquid in a capillary tube, it will be seen that the difficulty is much greater when it is a question of getting the height of the movable level of a liquid which is rising with rapidity under the eye of the observer, especially at the origin of the motion. It is even almost impossible, whatever care be used in the determination, to obtain it with strict accuracy.

Although I need not dwell upon a detailed description of the apparatus that I have heretofore used, I must, nevertheless, give a general idea of it, in order to show how I apply to it the *electric obturator* which is to be employed in all that follows.

Description of the Apparatus.—The apparatus that I have used in all my experiments on capillary tubes consists simply of two rectangular pieces of wood, A B (Fig. 1), fixed at right angles, one in the center of the other; the first serving as a support and the second carrying a quadrant, or divided quarter circle, which permits of placing the tubes at determinate inclina-

tions. Needles are fixed in the center of the graduation, and upon the circumference at points corresponding to the different inclinations. The tube, T, during experimentation, is held in an invariable position upon the vertical piece of wood by means of rubber bands. The vessel, V, containing the liquid, is placed under the vertical piece. A spherical spirit level, N, is placed upon the horizontal board, and another and cylindrical one, N', is fixed upon a bracket parallel with the horizontal line, the starting point of the angular graduation. Two thermometers are attached to the vertical piece, one of which gives the temperature of the liquid and the other that of the surrounding air.

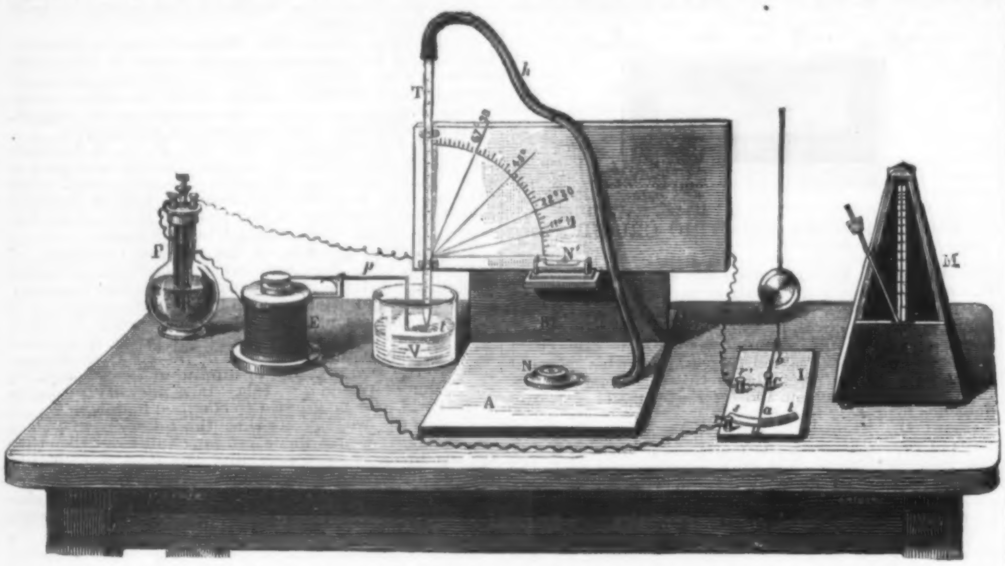


FIG. 1.—APPARATUS FOR THE STUDY OF CAPILLARY ATTRACTION IN TUBES.

Each capillary tube, which is of glass, enameled on one side, tapers at the ends and carries a scale divided into millimeters, the zero of which corresponds to that extremity of the tube which touches the surface of the liquid at the moment of the experiment. A rubber tube, *h*, affixed to the upper end of the capillary one, when properly manipulated, allows the liquid to rise in the glass tube, or expels it therefrom.

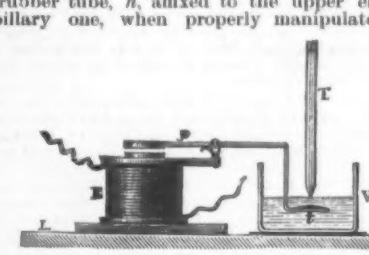


FIG. 2.—OBTURATOR.

The important part of the device is I, by means of which an automatic opening or closing of the tube is brought about at the moment fixed by the experimenter. This apparatus consists of the following parts: 1. Of an electro-magnet, E (Figs. 1 and 2), of feeble resistance. 2. Of a lever, *p*, with a spring, moved by the electro, and the extremity of which, bent twice at right angles, carries a rubber pad designed to close the tube hermetically. 3. Of a metronome (Figs. 1, 3, and 4), regulated for beating seconds or any other interval of time. And 4. Of a metallic needle, *a b* (Figs. 3 and 6), which plays the role of an interrupter, and which is movable upon a pivot, *c* (Figs. 1 and 6). When this needle is in its mean position, 2 or 2' (Fig. 5), its extremity, *b*, can be struck by the pendulum of the metronome during its vertical passage, and then set free at a slight distance therefrom, as in 3 and 3' (Fig. 5). According to the direction of the pendulum's motion, the needle is shoved by it to the right or left. The pendulum's extremity, *a*, which is bent at right angles, slides with slight friction over a horizontal circular zone, *s u t* (Figs. 5 and 6), a portion of which, *t u*, is formed of, or covered with, an insulating substance (ebonite), and another of which, *s u*, is metallic and communicates with a terminal, *r*. The vertical axis that carries the needle upon its pivot is of metal, and is connected with a terminal, *r'*.

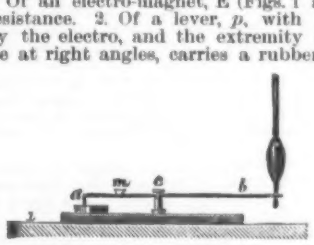


FIG. 3.—PENDULUM.

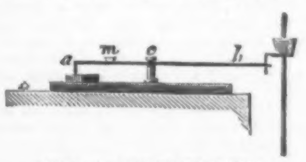


FIG. 4.—METRONOME.

Conducting wires, one of which passes through the electro, start from the poles of the pile, P, and end at the terminals, *r* and *r'*.

Mode of Experimenting.—The piece that carries the capillary tube having been arranged horizontally, by means of the levels, N and N', the tube is firmly fixed in position (here supposed to be a vertical one), after bringing its lower, tapering extremity to the level of the water, which latter will at once rush into the capillary space. On pressing the rubber tube with the fingers, all the liquid will be expelled from the glass tube, which will thus remain wet up to above the height that the liquid is to reach of its own accord. The pendulum having been set in motion, the needle is brought to the position 3 (Fig. 5), which corresponds to the closing of the circuit. The current passes into the electro, and this, becoming active, attracts the lever, whose pad closes the empty tube (Figs. 1 and 2). The apparatus is now ready for an experiment.

It is a question now of opening the tube at the beginning of a unit of time (a second). To this end, we move the needle by hand to a position where its extremity, *b* (Fig. 5, 1'), can be struck by the pendulum when it is passing in the vertical, and when it is going from right to left. The needle will thus be shoved in the same direction. When it reaches position 2', its appendages, *a*, will leave the metallic part, the current will be interrupted, and the electro will instantly allow the lever to escape, and this, pulled by its spring, will lower the pad and leave the aperture of the tube free. The liquid will at once rush in, and the pendulum, which has pushed the needle out of its reach at 3', will be able to pass and repass for one or more seconds, without causing a closing of the circuit and, consequently, of the tube into which the liquid is continuing to rise. If we wish to arrest the ascent at the end of one, two, three, or more seconds, we bring the interrupting needle to position 1, after the pendulum has passed the latter on its way toward the left. When the pendulum redescends, it will carry the needle along to position 2, where an electric communication will be instantaneously set up. After the pendulum has shoved the needle into position 3, the current, as well as the tube, will remain closed. It is then that we read and note the height to which the liquid has risen at the end of the time that we have counted.

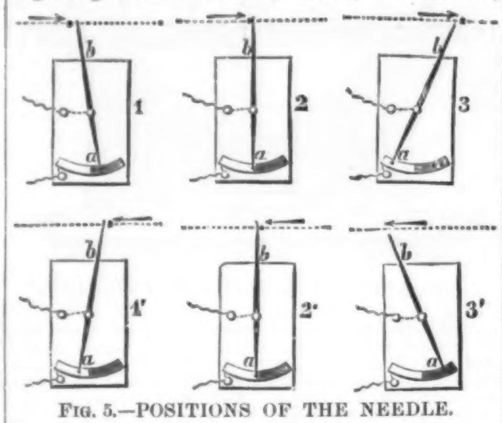


FIG. 5.—POSITIONS OF THE NEEDLE.

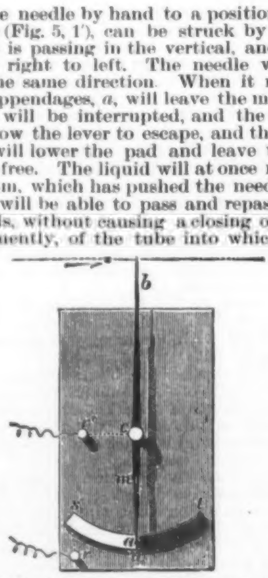


FIG. 6.—HORIZONTAL PROJECTION OF THE NEEDLE'S TRAJECTORY.

If we use a clock whose hand marks seconds, we shall merely have to read the number, taking care at the same time to note the moments that correspond to the opening and closing of the tube in the experiment. The experiment is repeated for the same time until we obtain concordant numerical results. Should slight differences exist between these, a mean is to be taken.

In order to apply the preceding apparatus to the metronome, there is no change to be made in the interrupter. We have only to adapt to the oscillating rod (which is somewhat wide) a bent metallic point, which will produce a contact with the interrupting needle when the pendulum is passing in the vertical. This would not occur with the same accuracy were it the rod that shoved the needle.

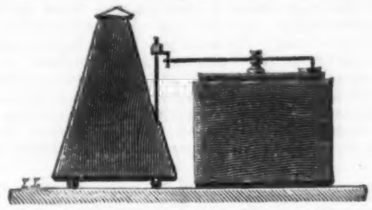


FIG. 7.—ELECTRIC INTERRUPTER AND METRONOME.

For counting the seconds, it would have proved an advantage to place the interrupter at the end of the pendulum's travel—a position that corresponds to the sound of the pendulum's scapement; but, with a little practice, it will be easy to count out of time, as is frequently done in music, or to subtract a half-second from the number of seconds marked or beaten by the pendulum or metronome from the beginning.

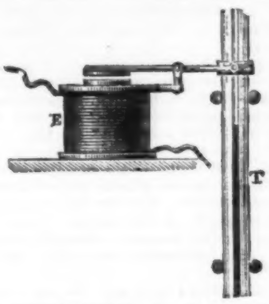


FIG. 8.—INTERRUPTER AT THE UPPER EXTREMITY OF THE TUBE.

If, nevertheless, we wish to place the interrupter at the end of the pendulum's travel—to the right, for example—in order to produce a passage of the current, it will be necessary to carry it to the left in order to effect a breakage of the current. In this case, slides or datum point stops will permit of bringing the interrupter without delay to the place that it is to occupy in order that the desired effect may occur.

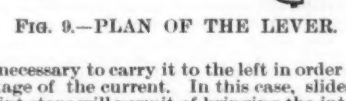


FIG. 9.—PLAN OF THE LEVER.

This process is less practical than the preceding. Moreover, it is better to utilize the force of the pendulum when it is at its maximum, that is to say, when it is passing in the vertical, than when it is at its minimum, or almost *nil*, that is to say, when it is nearing the end of its travel; for, in the first case, as the pendulum then has its greatest velocity, and consequently its greatest quantity of motion, it can easily overcome the resistance that the interrupting needle offers to it through its friction on the pivot and on the metallic or insulating piece over which its appendage slides.

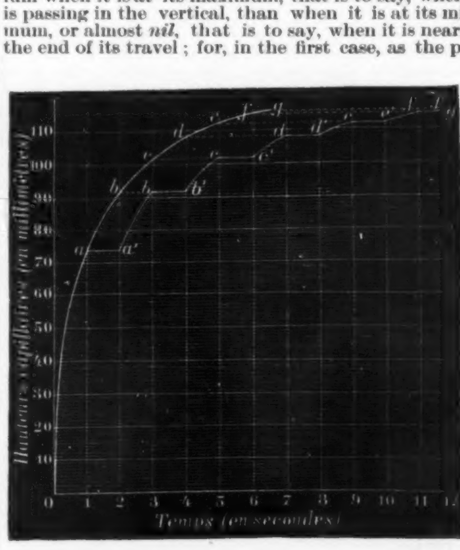


FIG. 10.—CAPILLARY MOTION REPRODUCED BY INSTANTANEOUS PHOTOGRAPHY.

On another hand, another difficulty would occur with the metronome in the second case, that is to say, should we desire to make the beginning of each unit of time coincide with the sound of the scapement; for the oscillations of the apparatus, although sensibly

isochronous, do not possess the same amplitude, the latter being a little greater when the metronome has just been wound up than when its spring has uncoiled to some extent. Consequently, the metallic contact that brings about a passage or breakage of the current would not always be the same as the end or beginning of an oscillation. It is for that reason that I had to dispense with this means.

The essential thing is that automatic opening or closing of the tube shall be done by the apparatus that marks the time, and such a result is obtained without difficulty by the means indicated above.

When the interrupter has been well regulated, it is firmly fixed in its normal position in order to prevent any accidental displacement. The electro, likewise, must be fixed in an invariable position.

When the liquids under experiment are of such a nature as to attack the obturator (such as nitric, sulphuric, and muriatic acids, potassa, etc.), recourse is had to another arrangement of the electric auxiliary, and which consists in placing it at the upper part of the tube, not in order to close the latter, but to lift it out of the liquid or to cause its lower extremity to dip thereinto. The tube can then slide with slight friction between the guides. It is attached to the lever appendages, as shown in Figs. 8 and 9.

The play of the apparatus is analogous to what it was before. A closing of the current lifts the tube above the level of the liquid in the vessel, and this is equivalent to a closing of the tube. A breakage of the current brings the tube to the surface of the liquid, and precisely to the height that corresponds to the zero of the graduated scale carried by the tube. The rest of the operation is finished as before.

This process is applicable to all liquids, and serves also as a control to the other.

When instantaneous photography is applied to the motion of liquids in capillary tubes, the use of electricity is advantageous. In fact, by this means, we can suddenly arrest the ascent of the liquid at the end of a unit of time. As the sheet of sensitized paper continues to move uniformly, the summit of the liquid column will trace a horizontal line, $a\,a'$, during the repose of the liquid. Upon the tube being opened anew at the beginning of a unit of time, and being closed at the expiration thereof, the summit of the movable column will describe the curve, $a\,b$, corresponding to such time. Then the tube is to be closed, and so on.

The succession of such effects will be represented by the series of broken lines, $a\,a'$, $b\,b'$, $c\,c'$, $d\,d'$, $e\,e'$, $f\,f'$, $g\,g'$ (Fig. 10).

Upon afterward bringing these successive curves into the same line, we shall form a single, continuous curve, $a\,b\,c\,d\,e\,f\,g$, which represents the movements of the top of the liquid column for the various corresponding units of time.—*C. Decharme.*

THE ORIGIN OF THE RED GLOWS.*

By Rev. SERENO E. BISHOP, Honolulu, Hawaiian Islands.

THESE brilliant phenomena first began to be observed on the 28th day of August, 1883. They have continued with varying but diminishing intensity for more than two years. They first appeared in great splendor along an equatorial belt of 18,000 miles or more. They gradually extended with reduced brilliancy to the temperate zones, exciting the wonder of Europe and the United States in November, 1883.

The most conspicuous of these phenomena take place during one hour or more before sunrise and after sunset. They may be considered as a great intensifying and prolongation of common twilight sky reflections, in consequence of a recent introduction into the higher regions of the atmosphere of some kind of finely divided matter which powerfully reflects the sun's rays, especially the red. The usual order of changes is as follows:

Clouds not obscuring the view, the horizon where the sun has just set is occupied by a bright silvery luster. Above this to a height of 30° or 40° a yellowish haze fills the Western sky. Although seemingly opaque and dense, the presence in it of Venus or the crescent moon shows it to be entirely transparent. This haze rapidly changes in color and extent, ranging through greenish yellow and olive to orange and deep scarlet. As the dusk advances, orange and olive tints flush out on all sides of the sky, especially in the east. The chief body of color gathers and deepens over the sunset, rapidly developing the red. In from 20 to 30 minutes after sunset, deep scarlet has overpowered all other hues, flaming along 60° of horizon and 10° of altitude. This rapidly sinks and intensifies. There is a dark interval above the red. The stars begin to appear. While yet the color flames low, above the dark space appears a repetition of the orange and olive hues. Seen against the night sky, these secondary reflections or after-glows are seemingly more brilliant than the primary ones. Again the colors change and deepen into red, and after the stars are all out, and the earlier flame has sunk below the horizon, and far later than any common twilight, a vast blood-red sheet covers the west. It has been seen rising as high 20°. As it sinks and rests low on the horizon, in the dark night sky, it precisely simulates the appearance of a remote and immense conflagration, for which it has in many places been mistaken. I have known our usual 30 minutes of twilight to be prolonged to 90, before the last glow disappeared.

In the dawn recur the same appearances, but in inverse order. In September, 1883, they were singularly impressive and even terrific, as the first low sullen incandescence rose and spread and glared among the stars as if the very heavens were in conflagration. Then, as well as at nightfall, a marked division occurs between the night glow and that nearest to the sun. During the earlier weeks of the display, the dark interval was often extremely distinct. One observer† described it as a "black bow." Another saw the shadow of the remote horizon sharply projected upon the under surface of the haze-canopy, but with fine serrations, probably the shadows of platoons of cumuli.* Evidently at that early date the canopy of floating haze had a well-defined under surface.

From the beginning, the upper limit of the night-glow has always been indefinite, since its light was reflected to it from the broad surface of the first glow, while the latter showed a clean shadow of the horizon from the sun itself. In general it may be said that the tropical displays of these glows at their birth during the first week in September as far surpassed the mild glows seen worldwide in November as the plunging surges of a tempest surpass the tripping crests of a breeze. The entire dome of sky above and around seemed to heave with billows of lurid light, as the portentous masses of color poured out of the pellucid blue, while the west outflamed in broad conflagrations.

In September, during the day, as well as after sunset, many portions of the haze canopy were noticeable as having a wavy or rippled structure.† A conspicuous object when the sun is high has been from the first the opalescent silvery glow around the sun. This occupies a circle of 25° radius or more. The outer part develops a pinkish hue, which against the blue sky shows lilac or chocolate tints. These have a singular effect when seen through rifts of cloud, as Capt. Penhallow ‡ saw them on September 18, 1,000 miles N. E. of Honolulu. This sun-glow has been particularly discussed by M. A. Cornu in the *Comptes Rendus* of September 23, 1884. He remarks peculiar modifications therein of the atmospheric polarization of the sun's rays. Prof. F. A. Forel has repeatedly discussed this sun-glow, which he has named § the "Cercle Bishop," after the first observer of the phenomenon at Honolulu. Prof. Huggins found this sun-glow putting an end to his previously successful photography of the solar corona.

The height of the main body of this haze in the atmosphere has been variously estimated at from 15 to 40 miles. The present writer, as the result of much and early observation, has no doubt that in the early part of September, 1883, no part of its under surface was less than 30 or 40 miles above the ground. All estimates should be based upon the first reflections, and not upon the secondary glows. No decisive tests of the nature of this reflecting matter have been secured. The spectroscope has distinctly indicated the presence of large quantities of aqueous vapor,‖ accompanied by other peculiar influences. Fresh fallen rain and snow have repeatedly yielded a dust of microscopic particles possessing the same constitution as the fine ash-fall from Krakatoa.

The most generally accepted theory of the source of this new matter in the sky attributes it to the great eruption of the crater of Krakatoa or Krakatao, in the Straits of Sunda, on the 27th of August 1883, one day before the first definite record of red glows, which were seen on the 28th, at both Mauritius and the Seychelles, 3,500 miles west of Krakatoa. Before considering the evidences in support of this theory, notice needs to be taken of two other hypotheses which have been advocated.

One of these assumes the meeting of our globe with some cosmic cloud of impalpable dust, which was arrested in the upper strata of the atmosphere.

The other hypothesis supposes the cosmic cloud to have been composed of hydrogen, which united with the oxygen of the atmosphere to form the aqueous vapor evidently constituting so considerable a part of this haze.

The latter hypothesis seems open to the objection that such uniting of the two gases is usually attended with active combustion, none of which was observed.

Both hypotheses suffer from the total absence of evidence that any such cosmic cloud did approach the earth on or before August 28, or since that time. The matter actually introduced into our atmosphere is brilliantly conspicuous in the sunlight. Yet we are asked to believe that a vast nebula of such matter approached unseen and enveloped the earth. In 1861, the tail of an immense and brilliant comet actually swept the earth. Yet so tenuous was the impinging matter that no traces of its presence were left behind. A cloud sufficiently dense to create the present haze must in its approach have presented the aspect of a most compact and refulgent body. So far from being possibly unobserved, it must have terrified mankind.

Another and most serious objection lies in the original narrow localization of this haze in an equatorial belt. It is difficult to conceive of a cosmic cloud possessing a mass adequate to the immense effects produced, which should not occupy such dimensions as to completely envelop the globe at once, producing glows simultaneously all over the earth, not to consider the improbability that the course of such a dense little nebula after collision should precisely coincide with the equator. It must be remembered that stray cometary or nebulous matter (not solid meteors) afloat in cosmic space, since it possesses small mass and feeble centripetal force, necessarily assumes immense volume and extreme attenuation, compared with which this haze is solidity itself. The entire quantity of this peculiar matter actually diffused in our atmosphere must originally have been equivalent to many cubic miles of solid matter, which represents a volume of cometary material immensely exceeding the dimensions of the largest planet. The actual localization of the first glows in the tropics thus precludes reference to cosmic sources, and compels us to seek a terrestrial one.

Many have felt that the long protracted continuance of this haze in the air necessitates the supposition of renewed supplies from fresh sources, as if perhaps the earth were continuing to traverse successive regions of cosmic vapors (which no one has seen). Had there been but one original introduction of the haze, must it not long since have been precipitated, and disappeared? But we have to consider how slow is the subsidence of even coarse common dust, especially in currents of air. The haze matter in question had probably 40 miles to fall. If only 20 miles, or 105,600 feet, it must fall 144 feet in a day to reach the ground in two years. It seems improbable that these ultra-microscopic particles could descend at one-tenth of such a velocity.* It seems likely, on the contrary, that the finer particles of this matter will continue suspended, and produce their glows for many years to come.

Leaving these nebulous imaginings, let us pursue the plain, if humble, historical method of inquiry. When and where were these phenomena first observed? Under what peculiar conditions and with what attendant circumstances did they appear? In what successions of time and place did they first occur, and to what actual point of origin on the earth's surface may they be traced?

Pursuing this indispensable method of physical investigation, we find that the earlier appearances of the sunset glows were as a rule immediately preceded by a peculiar veiling and discoloration of the sun's disk, commonly termed the "green sun." While the sky was cloudless, or faintly obscured by undefinable haze, the disk of the sun was described† as pallid, livid, bluish, coppery, greenish, "bird's egg hue," "plague-stricken." It could be directly viewed with the naked eye, and its spot distinguished. At the altitude of 40° the sun generally resumed its ordinary aspect, but again turned pallid and green as it descended in the west. In some cases the sunset glares immediately succeeded, while in others they were not reported, the haze probably having been too dense for the sun's rays to penetrate it obliquely, so as to be reflected from its under surface. The first appearances of the red glows were so intimately associated with the green suns that it is impossible not to treat them as different aspects of one and the same phenomenon.

It seems in place here to cite Mr. Whymper's observation ‡ of green sun and wonderful sky-glows combined. On the third of July, 1880, on the upper slopes of Chimborazo, Mr. Whymper witnessed an eruption of Cotapaxi, smoke from which drifted over the observer's position. Seen through it, the sun's disk assumed a peculiar green, while the changing colors of the sky "surpassed in vivid intensity the wildest effects of the most gorgeous sun-sets."

From such records as were accessible, I have constructed the accompanying tabulated statement of the earlier recorded appearances of the green suns and the red glows. The latitude and longitude of each locality are given in the table, with the date of the first appearance of the phenomenon at each point. The distance from Krakatoa is estimated in English miles, the number of hours in transit and the velocity of the current calculated. The source of information is specified for each of the seventeen different localities, three of which were on vessels at sea in the Pacific. To these, Maranham might be added. I lack the needed reference. At six of these localities, both the green sun and red glows were reported as having been seen on the same day. At four points only red glows were reported, and at seven only green suns.

The most remarkable fact evidenced by this table is that the earliest appearances of these phenomena are thereby traced along a line of points, successive from east to west, lying very near the equator, beginning at the Seychelles Islands in the Indian Ocean and running thence in successive days through Cape Coast Castle, Trinidad, Panama, and Fanning's Island, arriving at Strong's Island on September 7, having traversed a great circle of 17,600 miles in about 230 hours.

It thus appears that the original haze cloud, which first produced the red glows, swept west from the Indian Ocean in an equatorial stream or belt, which traversed more than two-thirds of the circumference of the globe at an average velocity of nearly eighty miles an hour. A precise estimate of its velocity between successive points is prevented by the imperfection of the observations made. The date at Cape Coast Castle is uncertain by one day. The dates at Seychelles and Mauritius are probably vitiated by the copious diffusion of volcanic smoke prior to the regular movement of the upper stream. It seems quite clear, however, that an average velocity of about 90 miles an hour during the first half of the course of this haze-stream became reduced to about 60 miles in its later stages. These data appear to favor the conclusion of Mr. S. E. Bishop,§ that a stream of vapors was discharged over and upon the upper surface of the atmosphere of the Indian Ocean, by a powerful *initial* impulse, which drove it straight in a great circle, independently of atmospheric currents, and that this stream gradually suffered retardation as it descended into the atmosphere, finally ceasing over the Caroline Islands.

Without necessarily accepting this writer's theory, showing how such an impulse would be generated by the rotation of the earth, it seems clear, at least, that the inception of the equatorial haze-stream and its attendant glows has been traced with positive certainty as far as the western side of the Indian Ocean, and back to the 28th day of August. Eastward of this, our search is arrested by a vast pall of volcanic smoke proceeding from the greatest eruption described in history. But if we stretch our line back through this obstructing veil, 30 hours in time and 3,500 miles in distance, we find ourselves confronted by the great final explosions of Krakatoa on the morning of August 27. Projected aloft from this crater by a succession of colossal explosions, a vast dome or cone of volcanic smoke on that day covered a region of not less than 400 miles in diameter with absolute darkness for many hours, and spread a deep gloom for not less than 1,000 miles in every direction. From the summit of this immense reservoir of vapors piled to an unknown height, the great equatorial haze-stream appears to have issued, and sped westward around the globe. We have unquestionably traced it to its source in the vapor-mass that overhung the Indian Ocean, less poetic than a cosmic nebula, but possessing reality, and with it have found the one sole and indisputable origin of the red glows which attended its course.

This does not imply that the swift equatorial smoke stream embodied the whole of the glow-producing medium. It seems more probable that the larger portion of the vapors which became slowly and irregularly diffused over the globe during the ensuing seventy days was drifted from the broad vapor mass after the special stream had ceased. Thus we find the Indian

* The third Prize Essay of the Warner "Red-light" Prize Essays.
The following are the successful competitors: ***First prize***, Prof. K. I. Kiessling, Hamburg, Germany; ***second prize***, Prof. James Edmund Clark, York, England; ***third prize***, Henry C. Maine, of Rochester ***Democrat and Chronicle***, Rochester, N. Y., and Rev. Sereno E. Bishop, of Honolulu, Sandwich Islands (the last two were of equal merit). ***Medals of honor*** were awarded to the following: Prof. Cleveland Abbe, Washington, D. C.; Prof. Winslow Upton, Providence R. I.; Prof. H. A. Hazen, Washington, D. C.; Prof. W. M. Davis, Cambridge, Mass.; Frederick Cowle, Lauriston, Tasmania, Australasia; and Rev. Robert Graham, LL.D., Errol, Scotland. The judges were Prof. Daniel Kirkwood, Bloomington University, Indiana; Prof. M. W. Harrington, University of Michigan; and Prof. Ormond Stone, University of Virginia.

† *Nature*, vol. 29, page 549.

* *Nature*, 29, 549.
† *Nature*, 29, 174.
‡ *Nature*, 29, 174.
§ *Archives des Sciences Physiques et Naturelles*, tome 13, p. 465.
‖ C. Michie Smith, *Nature*, 29, 28.

* John Le Conte, *Nature*, 29, 404.
† *Nature*, 28, pp. 576, 577; vol. 29, pp. 28, 76, 133, 181, 549.
‡ *Nature*, 29, p. 199.
§ *Hawaiian Monthly*, April, 1884.

peninsula untouched by the narrow stream which must have passed south of the equator. But 14 days afterward, the haze arrived in full force, and produced the green suns and red glows throughout Ceylon and Southern India, shortly afterward appearing in Aden and the Soudan. We also find the glows at New Ireland, 3,200 miles due east from Krakatoa, in four days after the last explosions. In all these cases the transportation was comparatively slow, and probably due to atmospheric currents.

We need to consider the adequacy of the eruption of Krakatoa to have produced atmospheric effects of such magnitude and extent, not only "*belting* the globe with flaming skies," as in September, but by November enveloping the entire sphere in these fiery glares. Can Krakatoa be shown to have probably ejected a *quantity* of tenuous matter sufficient for this result? And can it be believed to have delivered such matter at such a *height* that in its descent it would form a haze canopy from 30 to 40 miles above the surface?

We have absolutely and precisely traced the glows to their source, and so have the right to affirm that Krakatoa proved its colossal capacity to emit these vapors in such quantity and to such a height, by having actually done so. It is the objector's part to prove that it could not have done so, and did not. But waiving this advantage, we cite a preliminary official report on the nature and effects of the eruption of Krakatoa, made by Mr. R. D. M. Verbeek.* He makes an estimate of the quantity of those solid ejecta of the crater which were so coarse as to be speedily precipitated. This amounted to 18 cubic kilometers, or 4·5 cubic miles, two-thirds of which fell as ashes and pumice within a radius of nine miles. He believes that at least an equal mass was delivered at the highest parts of the column in the form of vapors and impalpable dust. It would be easy to present considerations to show that this finer portion must have vastly exceeded the coarser. But this might be speculative. We know that four and a half cubic miles of solid matter would overlay the entire atmosphere of the globe with a solid film of one seven-hundredth of an inch in thickness. This would doubtless be equivalent to many miles in thickness of such tenuous vapor and dust as have been floating in the upper ether.

As to the height of the column of ejecta emitted from Krakatoa at its highest activity, some estimate may be formed from known facts. The heaviest throes were very precisely determined† to have occurred at 9:55 and 10:45 A. M. on August 27. The latter one was immediately followed by a continuous downpour of mud and ashes upon the ship Charles Bal, then 30 miles distant.‡ Seventy miles away, trees were extensively shattered by the weight of wet ashes.§ Batavia, 100 miles away, was covered three inches deep with white ashes during the hours of total darkness following the greatest eruption. It seems impossible to find room for these facts on any estimate of the height of the eruptive column as less than one hundred miles. It is true that *light* ashes might have great lateral diffusion from a column of far less height, but mud and wet ashes must have plunged quite directly downward, so that a lateral throw of 30 to 70 miles must involve a vertical ascent of not less than one hundred.

The height supposed would have driven the eruptive column entirely through the atmosphere and far above it, so as to deliver its contents over the surface of the atmosphere, to settle slowly down through its upper strata.

That the great column did actually thus lift and rend asunder the mighty mass of the atmosphere above the crater is made probable by the unique oscillations of the barometers. A series of atmospheric waves was sped three times around the globe at the rate of 700 miles an hour.‖ The length of each undulation was one million meters, that of the lowest audible sound waves being 24 meters. Twenty miles away from the crater the mercury rapidly oscillated between the 28th and 30th inches. It is thus evident that in the vicinity of Krakatoa the upper layers of the atmosphere were swinging up and down through a vertical distance of from ten to twenty miles every 15 minutes. What could have done this less than an explosion driving clear through its entire depth?

As general evidences of the ultra-colossal character of the Krakatoa explosion may be adduced the following:

1. The waves driven upon the coasts of Anjer and Merak, 30 miles away, were found to have exceeded 35 meters, or 112 feet, in height.¶ Over the entire Anjer plain, fifteen miles by five, the inundation had uprooted every tree, and coral blocks of from 20 to 50 tons in weight had been torn from the bed of the sea and borne inland two or three miles.**

2. The detonations of the eruption were heard throughout a circle whose radius is 1,800 geographical miles,†† equal to one-fifteenth of the surface of the earth. Yet the heaviest could not be heard within a radius of 40 miles from the crater. The sounds must have proceeded from tremendous rendings of the air at an immense height, whence the sounds were easily spread to vast distances, while from localities beneath, the massive torrents of descending ejecta cut off the sounds like a wall.

3. Ashes fell ‡‡ at Singapore, 335 miles; at Buncalis, 915 miles N. W.; at Keeling, 1,200 miles S. W.; on the Australian coast, 1,050 miles E. S. E.; on the Arabella, 970 miles W. N. West. The entire area of ash fall was officially estimated as at least 750,000 kilometers,§§ or as large as the Southern States east of the Mississippi.

The history of the eruption shows that upon the collapse of the mountain, on the morning of the 27th, the eruptions became submarine; ‖‖ the ocean waters rushed into the burning depths. Under the pressure of many miles of water the lava and the waters commingled and struggled with geyser-like discharges of augmenting violence, until finally there arose a continuous column of white hot water and lava. Through the wide throat, apparently three miles in diameter, the

* *Nature*, vol. 30, pp. 10-14.

† *Nature*, 30, 12.

‡ *Nature*, 29, 140.

§ *Leisure Hour*, July, 1885, p. 487.

‖ *Nature*, 29, p. 181.

¶ *Nature*, 30, 14; *Leisure Hour*, Sept., 1885, p. 636.

** *Leisure Hour*, August, 1885, p. 556.

†† *Nature*, 30, 10.

‡‡ *Nature*, 30, 13.

§§ *Nature*, 30, p. 13.

‖‖ *Nature*, 30, p. 13.

Locality.	Lat.	Long.	Date.	Distance.	Hours.	Velocity.	Green Sun.	Red Glow.	Reference.
Krakatoa........	6° 10′ S.	105° 30′ E.	Aug. 27th, A. M.						
Mauritius........	20° 20′ S.	57° 40′ E.	" 28th, P. M.	3,600	30	120		R. S.	*Nature*, Vol. 30, p. 279
Seychelles........	4° 30′ S.	55° 20′ E.	" 28th, P. M.	3,480	30	116	G. S.	R. S.	" " 30, 280
Cape Coast Castle	5° 25′ N.	1° 15′ W.	Sept. 1st, A. M.	7,420	90	82	G. S.		" " 29, 133
Trinidad........	10° 30′ N.	61° 26′ W.	" 2d, A. M.	11,600	127	91	G. S.	R. S.	" " 28, 577
Barinas, Ven.....	7° 44′ N.	70° 22′ W.	" 2d, A. M.	12,220	128	96	G. S.		" " 29, 76
Panama........	9° — N.	79° 35′ W.	" 2d, A. M.	12,860	128	100	G. S.		" " 29, 152
C. S. Hurlburt...	17° — N.	125° — W.	" 3d, P. M.	16,000	201	80		R. S.	" " 29, 549
Fanning's Island.	2° 40′ N.	159° — W.	" 4th, P. M.	18,400	218	84	G. S.		" " 29, 549
Jennie Walker...	8° 20′ N.	155° 25′ W.	" 4th, P. M.	18,200	218	84	G. S.	R. S.	" " 29, 549
Zealandia........	5° — N.	163° — W.	" 5th, A. M.	18,800	230	82	G. S.		" " 29, 181
Maalaea........	20° 49′ N.	156° 28′ W.	" 5th, A. M.	18,300	229	80		R. S.	" " 29, 573
Honolulu........	22° 17′ N.	157° 52′ W.	" 5th, P. M.	18,400	241	76	G. S.	R. S.	" " 29, 174
Strong's Island...	5° — N.	162° — E.	" 7th, (6) P. M.	21,100	256	83	G. S.		" " 30, 537
New Ireland	5° — S.	152° — E.	" 1st, P. M.	3,200	107	30		R. S.	" " 29, 259
Madras........	13° 13′ N.	80° 12′ E.	" 10th, A. M.	1,900	332	6	G. S.	R. S.	" " 29, 28
Ongole........	15° 32′ N.	80° 8′ E.	" 10th, P. M.	1,900	342	6	G. S.	R. S.	" " 28, 576
Soudan........	15° — N.	32° — E.	" 24th.	5,100	672	8	G. S.		" " 29, 181

vast column drove upward, expanding and exploding as it flew into steam and pumice, till, reaching one hundred miles or more in height, its mingled solids and liquids had exploded in the vacuum into thinnest ether.

The ashy ejecta, as analyzed, were mainly of glass in the form of pumice, together with the solid constituents of sea water.* This vitreous matter, being comminuted by the force of the explosions to dust of ultra-microscopic fineness, formed, together with the vaporized sea water, a vast bulk of extreme tenuity and lightness above the atmosphere. Falling thence upon the upper strata of the atmosphere, and precipitating its coarser dust, its finer portions have continued suspended for more than two years in their ethereal encampment, and there are likely to abide for many years to come.

From the beginning, the white sun-glow has been very uniform, while the night-glows have been quite irregular, although it is believed they have always been perceptible. In the northern tropics, there has been a marked increase of brilliancy and continuity during each of the two winters. Probably the haze is distributed through the atmosphere in unequal and irregular drifts.

John Aitken's demonstrations of the necessity of dust nuclei to the formation of ice spicules in the atmosphere† indicate that such ice particles probably play a prominent part in the glows. Not improbably they would be in larger quantity in the tropics during the winter; and so the glows increase at that season. Varying atmospheric conditions would also at all seasons vary the amount of congelation.

In conclusion, the writer takes the opportunity to venture the surmise that a thorough study of the Krakatoa smoke belt of September, 1883, and of its dynamic conditions, may furnish material aid in elucidating the still mysterious problem of the belts of the planet Jupiter.

FUNGI INDUCING DECAY IN TIMBER.‡

By P. H. DUDLEY.

The fungi are leafless, flowerless plants, containing no chlorophyl, and instead of propagating by visible seeds, have only microscopic spores, which are freely disseminated by the air to resting places. If proper conditions for germination are present, the spore sends out a delicate mycelium, inducing sooner or later a decomposition of the structure of its host, in order partly to build up its own; and it is only later, when fructification takes place, that the presence of a fungus may be suspected.

The species of fungi named by writers as causing the so-called "dry rot" in timber are, namely: *Merulius lachrymans* Fr., *Polyporus hybridus* Fr., *Polyporus destructor*, *Thelephora domestica*, *Boletus destructor*, *Cerulius vastator*, *Agaricus melius*, and *Dædalia voræ*. The names of the first two are generally mentioned and do to duty for all occasions. The second is the one found so destructive to the English naval vessels built of oak.

The mycelium of a fungus is not sufficient, at present, for mycologists to identify species, and this is one reason why the list is so small. I have only found *Merulius lachrymans* Fr. a few times in bridges and cars, never on ties. The others of the list I have not found, but in their place many which are sufficiently destructive to satisfy all needs without any importing foreign varieties. While at this time I only add a few names of species, there are hundreds yet to be identified which aid in inducing decomposition of wood:

Lentinus lepideus Fr., scaly lentinus.
Agaricus americanus.
Polyporus applanatus Fr.
Polyporus versicolor Fr.
Polyporus lucidus Fr.
Polyporus salicinus Fr.
Polyporus nidulans Fr.
Polyporus sulfureus Fr.
Polyporus gilvus Fr.
Polyporus pergamenus Fr.
Polyporus abietinus Fr.
Polyporus pinicola Fr.
Lenzites vilas Pk.
Hydnum septentrionale Fr.
Fistulina hepatica.
Dædalea confragrosa Pers., *lenzitoid form.*
Panus stypticus Fr.

I have placed *Lentinus lepideus* Fr. first on the list, for in this immediate territory it is the one so destructive to timber of yellow or Georgia pine (*Pinus palustris* Mill.). I have also found it upon *Pinus mitis*. Being the first to call attention to its destructive influence, its brief technical description will not be out of place, as given in Cooke's "Handbook of British Fungi."

"Pileus fleshy, compact, tough, convex, then depressed, unequal, pallid-ochraceous, broken up into darker spot-like scales; stem stout, rooting, tomentose, or scaly; gills sinuate, decurrent, broad, torn transversely striate, whitish. On stumps of firs, rare (U. S.)." Monstrous forms occur in dark situations with or without a pileus. On the gills or laminæ are borne the spores, 3·5×8 micro-millimeters, curved, and one end apiculated, which drop out and are carried by the wind to some resting place. The mycelium fruiting only under very favorable conditions, the fruit is not easily found. A specimen is here shown. I have seen many thousands of ties destroyed by it without finding the fruit. Its mycelium is very abundant, and pierces the coarser cells of the wood with great rapidity, generating sufficient moisture, having an acid reaction, to carry on its destructive work, provided external currents of air and heat are not sufficient to dry the wood.

Examining many pieces of bridge timbers which were horizontal, I found where they had rested on others sufficient moisture had collected to germinate the spores, and the mycelia had followed the longitudinal cells from each way, until they had met in the center between the supports. The outer portions of the timber remaining dry did not allow the moisture to escape, and the fungus was destroying the inside, while the outside looked sound. I have here a part of a bridge plank. The moisture accumulated where it rested on the joists, the mycelia working each way and upward, leaving a thin portion of one-eighth to one-quarter of an inch in thickness, giving the appearance that it was all sound. The abundant fructification during a brief, warm rain in September, 1883, was the first indication of the destruction which had taken place. In ten minutes' walk from this hall, we could see many thousands of feet of timber destroyed by this fungus, while the cause of decay is hardly suspected.

The upright cells or tracheids composing the annual ring of the *Pinus palustris* Mill. are of two kinds; one of thin, and the other of thick walls. The former fill the inner part of the ring, the latter the outer portion, giving the great strength and hardness to the wood. Interspersed through the ring are a few resin ducts. In decay induced by its special fungus, the mycelium often separates some of the annular layers, and in most cases the thin-walled cells are softened first. On railroad sleepers, larvæ from one-sixteenth to one-eighth of an inch in length eat and bore through the softened fibers, so that in ties of four to seven years' service we often find little more than a series of nearly separated shells. The mycelium of this fungus, once in the roadbed, is, in summer time, ready to attack new ties of this timber as soon as put in the ground. I have noticed ties, taken up after a short service of six to eight months, which were covered on the bottom by the branching mycelium, and after drying one-eighth to one-fourth of an inch in depth, would crumble to dust. This is the so-called *dry rot*. It takes much longer for the mycelium to destroy the yellow-pine sleepers from the bottom and sides than when it has access to the ends. In the first case, it must nearly destroy the small medullary cells to reach the various rings, while from the end it has a larger area of the rings, which it readily follows. Painting the ends of the timber offers but little protection if the slightest opening occurs, as a spore can enter, grow, and carry on its destruction for a long time before it shows exterior decay.

The structure of each longitudinal cell of this wood consists of three lamellæ, a thin inner one surrounding the lumen, then a thicker one, then a thin outer one which joins that of the adjacent cell. Chemicals which dissolve the latter do not attack the other two, and *vice versa;* thus they can be separated. In the decay of this wood induced by the fungus described, the outer layer seems to be the last destroyed in many of the cases I have studied.

The decay of the yellow pine is a matter of increasing importance to many of the railroads in this vicinity, as they are depending more upon the use of this timber for ties than formerly, while for bridge timber and plank it is indispensable; and it would be difficult to supply its place in the construction of the frames of cars.

The mycelium of *Lentinus lepideus* Fr. is composed of small branching filaments measuring from one to two micro-millimeters in diameter. With the mycelium I generally find an abundance of crystals of one form of oxalate of lime. Sometimes small embedded cells of other fungi are seen; also other minute forms in adherent masses, the individual cells being quite beyond the definition of present microscopes. These lower species, which act as the allies of *Lentinus*, are difficult to trace. The destructive power of this fungus is very great, and it is causing enormous losses to users of timber, which are not realized or even suspected.

The remaining species of fungi in my list are those which I have thus far identified as inducing the so-called "*dry rot*" in various woods. *Polyporus versicolor* Fr. is very common, as I find it upon the sap-wood of the white and red oak, and chestnut ties; also upon the sap-wood of chestnut and locust posts, and on the sap-wood and heart-wood of wild cherry, and once on hemlock boards. As a rule, it is more abundant on sap-wood of the oak than on chestnut ties. My observations refer to the entire length of the Boston and Albany R.R., and parts of many other roads in Massachusetts. On the heart-wood of the white oak

* *Nature*, 30, p. 13.

† *Nature*, 29, p. 403.

‡ A paper read before the New York Academy of Sciences, January 4, 1886. From the Transactions of the Society.

ties, I have only identified *Polyporus applanatus* Fr., which also attacks the sap-wood of many other kinds. The heart-wood of chestnut ties is not so quickly attacked by fungi as some other woods, since most of them are removed on account of mechanical destruction of the fibers under the rails before decay takes place. I have several samples of the mycelium in chestnut tie (this one from the yard of the Grand Central Station), but have only found a few undeveloped efforts of fructification.

Fistulina hepatica was found on chestnut wood. The special habitats of the others need not be mentioned. These higher species of fungi are some of those which induce the so-called "dry rot" in timber, so often considered as taking place when the wood is perfectly dry. This is a misconception, as it is impossible for decay to commence without moisture, sufficient heat, and access of air to supply the amount of oxygen needed in the reduction of the tissue to lower compounds. "Dry rot" was named from the effect produced, and to distinguish it from the so-called wet rot. It has been an unfortunate designation, misleading many people, and causing them to believe that timber will rot when dry, and hence proper precautions have not been taken to prevent decay, on the supposition that it would occur in any event. When a fungus has attacked a piece of timber, and subsequent dryness arrested further decay, the tissue affected cracks and crumbles to dust, and people often tell me "there is the evidence of dry rot destroying dry timber"—an effect mistaken for a cause.

The mycelia and fruit of the fungi given in my list all show an acid reaction; and in the decayed yellow pine an acid was associated with a gelatinous mass, insoluble in alcohol, but partially so in hot water. A drop of the latter on evaporating left a gummy residue, and small crystals formed similar to those of oxalate and phosphate of calcium. By adding other reagents, a variety of different crystals were produced.

From the fruit of *Polyporus pinicola* Fr. a considerable quantity of phosphoric acid, potash, and lime was obtained. The watery extract from this fungus nearly resembles, in composition, the artificial preparations used for the cultivation of moulds, and is quickly transformed by them in a few hours, showing an abundance of yeast cells and rhombohedral crystals. This is a feature of great significance, being an important aid in hastening decomposition, at least. If there is a free aerial growth of the fungi, drawing its supply of oxygen from the air, there is a rapid destruction of tissues, and little is left of the structure. When the air is limited, there is a slower destruction, and more of a fermentative action. In the latter, in the many cases so far studied, I have found an abundance of crystals. The so-called "wet rot" is the result of slow fermentative action, and, when produced by the lower order of fungi, *Sphæriacei*, the mycelia found in the cells are dark colored and jointed. These mycelia are sometimes of long, and again of nearly spherical cells, which pierce the cell-walls of the wood and fill the medullary rays, making them look dark. Some species fruit in the cells near the outer surface. I have a piece of one of the original oak ties put down and completely covered by sand and paving, in the Grand Central Station, in 1871. It was taken out last month. The strength of the wood is destroyed, and it will crumble on further drying.

I found several budding cells of ferment similar to the yeast plant in appearance, and a few cells of the genus *Protococcus*, and an abundance of dark hyphæ, which give color to the wood in streaks. In what were checks in the wood when put down are the remains of perithecia of some of the *Sphæria*. The action here was very slow but sure; the outer lamella of each cell being destroyed more than the others. By wetting and careful manipulation, they can be separated, showing their form more perfectly than those obtained by the ordinary maceration. Some of the *Sphæria* grow under the bark of live trees, sometimes killing them, and are ready, as soon as vital functions of the tree cease, to pierce their host with the abundant hyphæ, and carry on their work of destruction.

I find on unpainted telegraph poles many places where the growing perithecia have burst and broken one to two layers of the wood cells; and this is repeated as fast as the proper conditions ensue, thus aiding in the mechanical destruction of the tissue. Near the ground line, other fungi send out mycelia which follow down the cells of the wood rapidly, but pierce the wood transversely in a slower manner. As the mycelia get farther away from the air supply, the fermentative action becomes more marked. I mention these points for the reason that, when examined separately, it is hard to understand their connection; and it is the consideration of these two extreme conditions which has led to part of the controversy regarding the relation of fungi to decaying wood. There is less real distinction between the so-called "dry rot" and wet rot than is usually supposed, as both must have moisture, a suitable temperature, and some air to induce decay. Though the final result is the same in all cases, it does not occur in the same way in all kinds of wood.

The subject must be treated specifically, and not in the general manner adopted by writers. Each species of tree has special fungi, as it has insects, which are not found to any extent upon other kinds of wood. Red cedar, cypress, yellow pine, are not affected, as a rule, by the same fungi which quickly destroy the sycamore, maple, hickory, and basswood.

The structure of all these woods, their stored products, and the intercalated substances in their cellulose walls, differ from one another, as do each of our extensive flora of over four hundred species, and they are distinguishable under the microscope by a difference of cell structure, arrangement, and chemical products as readily as the botanist recognizes them by exterior growth of form, leaves, flowers, or fruit.

The chemical composition of wood is not practically alike, as recently stated, but differs even in the sap-wood and heart-wood of the same species. Some of the woods have compounds in their cells easily induced to decompose and start the wood tissue, while others have different compounds, requiring inducing agents of greater intensities to begin decay.

A study of the growth and functions of the fungi enables us to understand why, in practical operations, it is so difficult to prevent large timber from decaying internally, while remaining sound upon the exterior. The spores so abundant in the atmosphere find ready lodgment in the checks of the timber before it is thoroughly seasoned. These are inclosed by boarding painting, or exterior treatment, or even exposed to the sun so as to dry the outside and thus prevent the evaporation of the internal moisture, and the spores germinate and either grow a mycelium or set up the fermentative action, destroying the inside of the timber, leaving a mere shell outside. This was the case with the painted Howe truss bridges erected for the Western railroads, many of them rotting in four to five years. Roads which were too poor to paint the bridges the first year, found they lasted longer. These were very instructive lessons to me, and in 1873, when designing and erecting a series of long railroad trestles, I made my posts six by eight inches, using two, set three inches apart. This allowed them to season, and gave me about the same factor of safety as one ten by ten, which would not season, but would rot in six to seven years. And my trestles are still in use.

The exterior coatings intended to preserve the Nicholson pavement blocks was about the most effective means which could have been used to destroy them. Many other failures of treated timber are due to this same cause, namely, inclosure of the spores, their growth and fermentation.

I have here a piece of wood, used for the sheathing of freight cars, which has already undergone initial decay. Its cells contain the germs to destroy it. A coat of paint on the outside, and a little moisture inside the car, would complete the decay. Cars sheathed horizontally retain moisture in the tonguing and grooving longer than those vertically sheathed, and in consequence they are destroyed sooner by the growth of fungus, seemingly a trifling affair, but really of great financial importance.

Some efforts to preserve certain timber for some places have been successful; but attempts to preserve all kinds and sizes on the same general plan have resulted in many costly failures, and large corporations have lost faith in such efforts to prolong the service of the wood. Why some succeeded and others failed hardly excited a query, much less an investigation; and hence good and poor methods were equally condemned.

The proof that untreated wood is stable in some conditions is very abundant. Timber and plank in the roofs of foreign buildings are reported to be in sound condition after a service of eight to ten centuries. Piles which were submerged in water and mud are also reported sound after as long service.

We have much older evidence of the preservation of vegetable and animal tissue than that contained in written records. I have sections of coniferous branches supposed to have formed part of the last dinner of the mastodon exhumed in Jamestown, N. Y., some years since, and the wood fiber is probably many thousand years old, as the mastodons have long since been extinct. Dr. Hubbard exhibited here last winter a piece of the Siberian mammoth skin, which must have remained in the ice for thousands of years. It was dried, and in this condition will last indefinitely. Last week Dr. Hubbard gave me a piece, to which I have applied moisture, and it is now undergoing decomposition—furnishing a rare morsel for countless bacteria.

The evidence of the destructive influence of fungi is older than that of the preservation of tissue. In the beautiful agatized woods of the Triassic period, recently shown here, I find the mycelia of the fungi, inducing their decay, preserved by the infiltrating medium which agatized the woods.

We daily see posts and telegraph poles, after three to four years' service, decaying near the ground line, but above in better condition.

By comparing the difference of service, it can be seen how little change is required to render unstable what would be stable under other circumstances. In roofs there are dryness, circulation of air, plenty of spores, and sufficient temperature to germinate, but the necessary moisture is absent. In the case of submerged piles, there is excessive wet, with insufficient temperature, and exclusion of air, either to carry spores or permit them to grow. In the case of the posts and telegraph poles, we have the spores, the moisture, and the necessary temperature in summer for germination, and decay ensues. The last stated conditions are those in which the great bulk of railway sleepers are placed, and decay will result unless precautions are taken to prevent it. It is not realized how thorough these precautions must be until thousands of decaying sleepers have been examined. In many cases it seems as though each individual fiber must be protected, not only to prevent the germination of spores, but from the stronger attacks of mycelia, which are in many old roadbeds.

To obtain the best results, the *kind* of wood for the service must be first considered. However, this general statement can be made—the tissues of all wood remain sound or decay, according to surrounding conditions. An inducing cause is necessary to start decomposition, which is the function of some of the fungi.

In the discussion, Prof. Trowbridge remarked upon the great practical importance of the study, and fully agreed with Mr. Dudley that moisture must be present to start decay. Wood in the roofs of buildings had lasted over two thousand years, and was still sound. The bridges put up by Towne, which gave him his great reputation, were covered, the timber kept dry, and some of them were still in use, and sound. In reply to his question whether there was any process which would preserve the timber, Mr. Dudley said that could not be answered generally. Small sizes of some kinds of timber had been preserved for some length of time, but there was, as yet, no successful treatment for all kinds of timber for all conditions of service.

Mr. Dudley, in answer to Mr. Collingwood, said that microscopic examination of different woods showed more in relation to the strength than the durability, though it would determine whether the stored products in the medullary rays were in the form of starch, the most stable form, or in sugar, glucose, etc. The catalpa, by its structure, does not indicate the great durability ascribed to it. Woods which have large bundles of medullary rays filled with compounds are more easily induced to decay, as a rule, than those which have smaller bundles. The microscopical examination would show at once whether incipient decay had commenced. In cutting timber and preparing it for use, it was impossible to prevent the access of numerous spores of various fungi in the air, and when proper conditions were present, they would germinate.

Thoroughly seasoned wood could be painted with advantage, otherwise it was an injury, because it held the moistened spores in the wood, and decay would take place.

Mr. W. Barclay Parsons gave illustrations from his experience of the variation in the durability of timbers and bridges under like conditions, and discussed the matter of painting and covering bridges. In one old bridge, the oak posts were sound, but the pine chords were gone.

Mr. Dudley said it was economical to paint bridges when the timbers were small and well seasoned; but the joints and ends of the timber must be well protected. Timber should be seasoned under cover, and not in the sun. He thought bridges were better covered than painted.

Dr. Schoeney discussed the subject of fungi attacking wood as being analogous to human diseases, and its bearing upon the germ theory. In answer to his question, Mr. Dudley said he thought the mycelium could penetrate the epidermis and corky layer of living trees if moisture could soften them.

Dr. Britton briefly described the life history of these higher fungi.

President Newberry commended the paper, and spoke of the importance of the study. He had in his museum specimens of wood from the Egyptian catacombs, which, by being kept dry, had been preserved three thousand years; moisture is necessary for decay, and there is no "dry rot."

Mr. Dudley said the first Nicholson pavement was of seasoned wood, while later unseasoned wood was used, and the pavements were short-lived. He thought that it was practicable to exhaust air, and fill pores of small timbers with antiseptic fluid, but not of all kinds of large timbers.

BARK BREAD.

MOST travelers in Norway have probably had more than sufficient opportunities of becoming acquainted with the so-called "fladbrod," flat bread, of the country. Few, however, among them who have partaken of this dry and insipid food may possibly be aware that in many districts, more especially in Hardanger, the chief ingredient in its composition is the bark of trees. This substitution of an indigestible product for *bona fide* flour is not necessarily a proof of the scarcity of cereals, but is to be ascribed rather to an opinion prevalent among the peasant women that the bark of young pine branches or twigs of the elm is capable of being made into a thinner paste than unadulterated barley or rye-meal, of which the Norse housewife, who prides herself on the lightness of her "fladbrod," puts in only enough to make the compound hold together.

The absence of any nutritive property in bark bread, whether made with elm or pine bark, and the positive injury it may do the digestive organs, have of late attracted much notice among Norwegian physiologists, and the editor of *Naturen*, with a view of calling the attention of the public to the subject, has, with the author's permission, reprinted some remarks by Dr. Schübeler on the history and character of the bark bread of Scandinavia. From this source we learn that the oldest reference to the use of bark bread in Norway occurs in a poem ascribed to the Skald Sighvat, who lived in the first half of the eleventh century. In the year 1300 the annals of Gothiand record a season of dearth, in which men were forced to eat the bark and leaf-buds of trees, while then, and during the later periods of the middle ages, the frequent failure of the crops in all parts of Scandinavia led to the systematic use of the bones and roe of fishes as well as the bark of trees as a substitute for genuine flour; and so extensively was the latter substance used that Pastor Herman Ruge, who in 1762 wrote a treatise on the preservation of woods, has drawn attention to the almost complete disappearance of the elm in the Bohus district, which he ascribes to the universal practice in by-gone times of stripping the bark for the preparation of bread.

In Nordland and Finmark the root of *Struthiopteris germanica* and other ferns, as well as the leaves of various species of Rumex, have been largely used with barley-meal in making ordinary bread as well as "fladbrod." In Finland the national "pettuleipa" (bark bread), which was in former times almost the only breadstuff of the country, still ranks as an ordinary article of food in Kajana and in the forest regions of Oesterbotten and Tavastland. Here it is usually made of the inner layers of the pine-bark, ground to a meal, which is mixed with a small quantity of rye-flour to give the requisite tenacity to the dough. The Finlanders of an older generation showed marvelous ingenuity in composing breadstuffs, in which scarcely a trace of any cereal could be detected in the mixture of bark, berries, seeds, bulbs, and roots of wild plants, which they seem to have accepted as a perfectly legitimate substitute for corn bread. In the interior of Sweden, according to Prof. Save, the *best* bread of the peasants consisted till the middle of this century of pease, oats, and barley-meal in equal proportions, while in the ordinary daily bread the husks, chaff, and spikes of the oats were all ground down together. In bad seasons even this was unattainable by the Dalekarlian laborer, who had to content himself with pine-bark bread.—*Nature.*

THE COMPOSITION OF AIR.

SOME recent experiments to determine the average composition of atmospheric air have been described to the Académie des Sciences by MM. Muntz and Aubin. This order of researches was initiated by Regnault, who established the mean composition of the air by multitudinous analyses of the contents of glass tubes sent by himself to correspondents in different countries, who opened these tubes, and, after they were filled with the air of the locality, returned them to Paris, where the analyses were made under conditions permitting the attainment of great exactitude. MM. Muntz and Aubin have not been able to improve upon the method of Regnault; but they took advantage of the French scientific mission to Cape Horn to secure fresh samples of air from a locality where it might be supposed to possess a perfectly normal composition. The mean of numerous samples taken under different weather conditions shows the proportion of oxygen to be 20·864 per cent. by volume. The air of Paris, according to two samples taken in a street in July, contains 20·92 per cent. of oxygen. Regnault's determination for Paris air was 20·960; and for all his analyses the maximum and minimum limits were 21·015

and 20·300 per cent. respectively. It may at first sight appear strange that the air of Paris should contain a higher proportion of oxygen than the decidedly fresher locality of Cape Horn. The experimentalists are careful to state, however, that their system of analysis has its limits, and too great importance should not be ascribed to minute decimal proportions. They content themselves with drawing the general conclusion that the chemical composition of air is practically the same with regard to oxygen everywhere, but that slight variations of this composition may be detected from time to time.

LIFE AT THE BOTTOM OF THE OCEAN.

Among other animals living at great depths in the ocean are the lamellibranchiate mollusks—animals that derive their name from the arrangement of their branchiæ, these being two in number, on each side of the body, and having the form of very thin plates, provided externally with transverse lines. These animals have a bivalvular shell, and some of them, such as the oyster, clam, mussel, and others, are common on our coasts. The various species are found from the edge of the sea down to a depth of 16,000 feet. At this depth the Challenger collected three different genera (*Arca*, *Leda*, and *Limopsis*), and the Talisman one genus—*Neæra* (species *lucifuga*).

The Saphodes are very singular mollusks, which were regarded by the earlier naturalists as worms, and the structure, development, and zoological place of which are known to us through the remarkable studies made of them by Lacaze Duthiers. These animals live from various depths near the surface down as far as to 13,800 feet. They are distributed throughout all the seas of the globe, and we find fossil species of them in the Devonian deposits.

The Brachiopods have a wider geographical distribution than any other mollusks, and are found at the greatest depths that have been explored with the trawl. The naturalists of the Challenger took the *Terebratulina Wyvillei* at the depth of 17,380 feet. These mollusks live in warm and cold seas and in puddles of water left at low tide upon the coast. A few years ago, no more than ninety species were known, but, as the result of submarine exploration, we now know 120.

The Heteropods are pretty animals that are as transparent as glass and are decorated with bright colors at different parts of the body. Some of the species are destitute of shells; others, such as the Atlantes, on the contrary, have a sufficiently large one to afford them shelter. They live out at sea, near the surface, and in the tropics are found in large numbers.

The name "sea worm" has been applied by zoologists to animals whose body is symmetrical laterally, and annulate or formed of similar segments, and which are destitute of articulated appendages. The name "worm" generally awakens a feeling of repugnance in those to whom it is mentioned. It might seem that all beings thus designated ought, as regards their form and color, to be the disinherited ones of nature, and that there was nothing in their life and habits worth attracting attention. Such is far from being the case, however, for it is among the worms, perhaps, that we meet with the most elegant and graceful marine animals, as well as the most richly colored, varied, and brilliant ones. These animals have very dissimilar modes of existence; some are domestic, and others are erratic. The former construct a dwelling made of strong tubes, made of a material which they themselves secrete.

During the cruise of the Talisman there was captured, off the coast of Morocco, at a depth of between 2,300 and 6,500 feet, a species of Annelid that inhabits one of the most singular dwellings that can be imagined. Instead of occupying a calcareous tube, as the Serpulas do, or a sheath covered externally with various little solid bodies, as the Terebellos do, it lives in a tube formed of a horny substance and closely resembling a quill. The likeness is so strong, in fact, that inexperienced persons who saw these tubes supposed that a lot of goose quills that had fallen into the ocean had been dredged up.

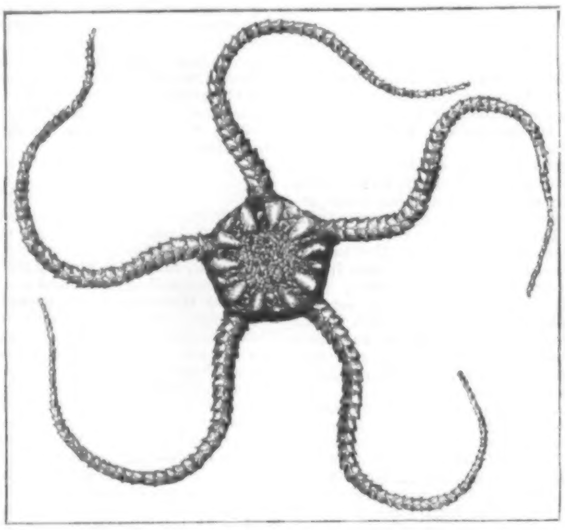


Fig. 2.—OPHYOMUSIUM TALISMANI.

The *Hyalinæcia Maiheuxi*, the species that has the singular habit of sheltering itself thus, appears to be very abundant at various muddy points of the ocean bottom, since, where it was found, hundreds of specimens were taken.

The Echinoderms are animals whose parts radiate from a vertical axis, and which have a dermic frame incrusted with lime and covered in certain forms with spines that have caused naturalists to give them the name they bear (from *echinus*, hedgehog, and *derma*, skin). Of all the animals living at great depths, they are the ones whose species occur in greatest abundance. They are found at as great a depth as 16,000 feet, and the variety of their forms seems to be infinite.

One of the most important groups of them is that of the Crinoids. The free Crinoids, such as the Antedons and Actynometras, are certainly related to the Echinoderms that are provided with distinct arms—the Asterias. Thus, at a depth of 8,690 feet in the Atlantic there are found Asterias which have a dorsal peduncle—a sort of imitation of the stem that fixes young Comatulas and adult Crinoids.

To the group of Asterioids characteristic of the deep sea fauna belong the Brisingas—beautiful star fishes, whose flexible arms are sometimes nineteen in number. These brilliant animals (Fig. 1), whose color is of an orange red, usually shed their arms when they feel that they are captured and are being hauled up, and it is only exceptionally that it is possible to observe them intact. Charles Absjordsen, who was the first to discover them off the coast of Norway, a little below Bergen, at a depth of 200 fathoms, could not escape a feeling of admiration in the presence of the phosphorescent light that was emitted from their bodies and arms. "When complete and intact," says he, "as I have once or twice seen it under water in the trawl, this animal is singularly brilliant, and it is a genuine *gloria maris*." He therefore gave it the name of *Brisinga*, which is that of one of the jewels of the goddess Freya.

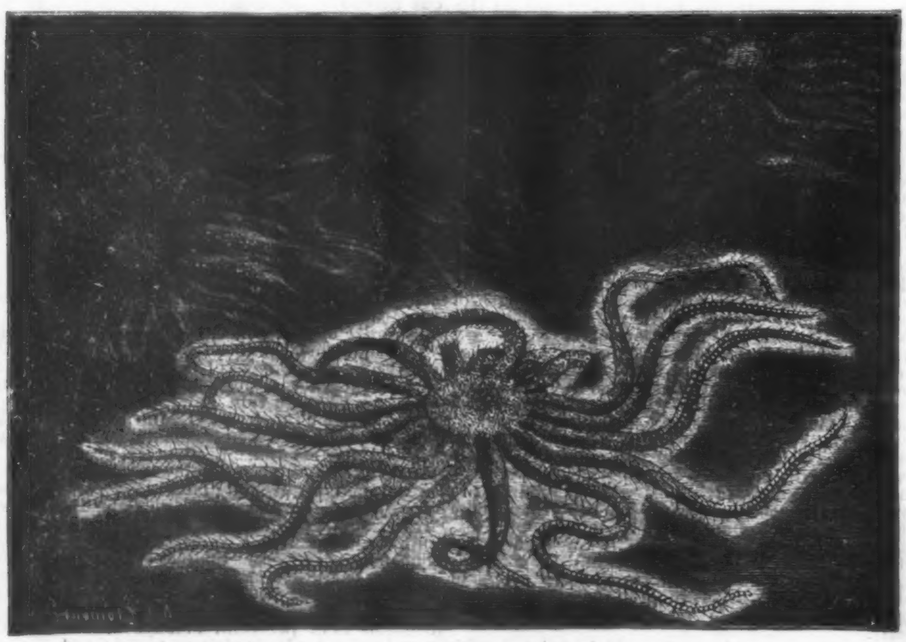


Fig. 1.—LUMINOUS STARFISH (BRISINGA ELEGANS).

During the course of the dredging performed in the Gulf of Mexico under the direction of Mr. Alexander Agassiz, an Asteria was taken which, through the simple organization of its arms, tends to establish a connection between the Brisingas, which belong to the order Asterioids, and the Echinoderms, that constitute the order Ophiurioids. In the *Hymenodiscus Agassizii* the body has the form of a perfectly circular disk, from which start twelve arms.

The Ophiurioids abound at great depths. During the course of the Challenger's cruise more than five hundred species of them were brought up in the trawl.

One of the most abundant of the genera in the Atlantic, at depths of between 2,500 and 11,700 feet, is the one called *Ophyomusium* (Fig. 2). In certain of these animals the disk plates are cemented together, and, as a whole, have the aspect of a beautiful mosaic.—*La Nature.*

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